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RACT (Reasonably Available Control Technology) Determination for Five Industry Categories in Florida

PEDCo-Environmental, Inc.
Cincinnati, OH

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Section 172(b)(2) of the Clean Air Act as amended August 1977, requires that SIP revisions "provide for the implementation of all reasonably available control measures as expeditiously as practicable." The use of RACT for stationary sources is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. The purpose of this report has been to identify control techniques that best represent RACT for particular emission sources in TSP nonattainment areas in the State of Florida. These sources include phosphate process operations; portland cement plants; electric arc furnaces; sweat or pot furnaces; materials handling, sizing, screening, crushing, and grinding operations.

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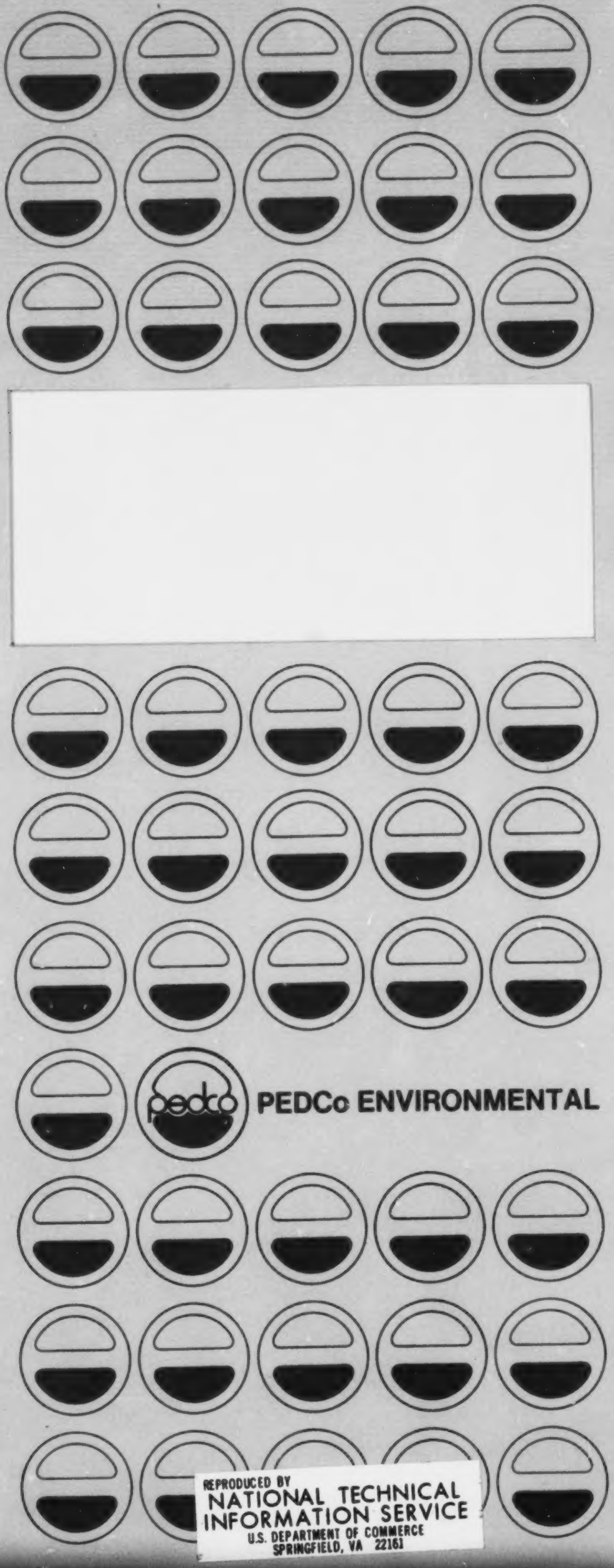

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RACT DETERMINATION FOR FIVE INDUSTRY CATEGORIES IN FLORIDA

by

PEDCo Environmental, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

Contract No. 68-02-3173
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Project Officer

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U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV
ATLANTA, GEORGIA 30308

November 1980

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SECTION 1

INTRODUCTION

National Ambient Air Quality Standards (NAAQS) for total suspended particulates are now being exceeded in portions of Hillsborough and Duval Counties in Florida. The lowering of particulate emissions within these areas requires that new or modified control strategies be developed to ensure that all reasonably available controls are used.

1.1 BACKGROUND

Two areas in Florida have been designated as nonattainment for total suspended particulates. They are defined as follows:

> the portion of Hillsborough County that falls within the area of the circle having a centerpoint at the intersection of U.S. 41 South and State Road 60 and a radius of 12 kilometers, and
>
> the downtown Jacksonville area in Duval County located just north and west of the St. Johns River and east of I-95 and south of Trout River.

Any particulate source that has a significant impact on ambient particulate concentrations within the designated nonattainment area are required to use Reasonably Available Control Technology (RACT) to control particulate emissions.

The application of RACT to existing stationary sources is a required part of the particulate nonattainment corrective portion of the State Implementation Plans (SIP). PEDCo investigated five of the major industry categories that represent the type of sources that are located in the two Florida nonattainment areas to assist the state in determining specific RACT emission limitations. These categories are:

Phosphate process operations

Portland cement plants

Electric arc furnaces

Sweat or pot furnaces

Materials handling, sizing, screening, crushing, and grinding operations

1.2 DEFINITION OF RACT

Section 172(b)(2) of the Clean Air Act as amended August 1977 requires that SIP revisions "provide for the implementation of all reasonably available control measures as expeditiously as practicable." The use of RACT for stationary sources is defined as "the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility."[1]

RACT is no longer defined by Appendix B, Code 40 of the Federal Register, Part 51, entitled "Examples of Emission Limitations Attainable With Reasonably Available Technology." Reasonable availability is now based on the technological and economic feasibility of the control, and requires stringent and even "technology forcing" control measures.[1]

Although consistency in the application of any regulation is important, determination of the "economic feasibility of a control may be very source specific."[1] Therefore, it is possible that exceptions will be made to any RACT regulation on the basis of economics. Such exceptions, however, are expected to be rare. Every effort was made to make the recommended RACT determinations specific for the affected plants in Florida.

The RACT emission limitations submitted in a nonattainment SIP revision are used to calculate the emission reductions needed to attain the NAAQS. Therefore, any deviations from these emission limitations are treated as SIP revisions. For this reason RACT regulations should be adopted only after sufficient study to ensure that they are indeed reasonable for the area in question.

Some of the confusion surrounding RACT stems from the comparision of RACT with other control requirements. Table 1-1 gives a comparison of RACT, Best Available Control Technology (BACT), and Lowest Achievable Emission Rate (LAER) control requirements. Although LAER will generally be more stringent than BACT and BACT will generally be more stringent than RACT, in some instances the required controls may be identical. This would occur if the costs of installing controls at a new source were the same as those of retrofitting controls at an existing source, or if the cost were relatively low. The RACT control would be less stringent than BACT in cases where, for technological or economic

TABLE 1-1. COMPARISON OF RACT, BACT, AND LAER REQUIREMENTS

Control requirement	Acronym	Applicable emission sources	Definition	Source of definition	Stringencies of requirement[a]
Reasonably available control technology	RACT	Existing sources in nonattainment areas	The lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available, considering technological and economic feasibility	Memorandum of December 9, 1976, from the Assistant Administrator of Office of Air and Waste Management	Least stringent
Best available control technology	BACT	New or modified sources in an attainment area subject to Prevention of Significant Deterioration regulations	An emission limitation based on the maximum degree of reduction determined on a case-by-case basis, taking into account several factors, including cost, energy, and technical feasibility	Section 169 (3) of the Clean Air Act as amended 1977	Moderately stringent
Lowest achievable emission rate	LAER	New or modified source in nonattainment areas	The emission rate of the most stringent limitation contained in any State Implementation Plan for such source category or the most stringent limitation achieved in practice anywhere, whichever is more stringent (with no allowance for economic factors)	Section 171 (3) (A) and (B) of the Clean Air Act as amended 1977	Most stringent

[a] In some circumstances, control requirements may be equal for RACT, BACT, or LAER, but the stringency order may never be reversed.

reasons, controls considered feasible for a new or modified source would be unreasonable if an owner were required to retrofit them at an existing source.

The following information sources are used for guidance in RACT determination:

New Source Performance Standards

Documents regarding particulate emission control techniques

Existing state and Federal regulations, especially those in Region IV

Information gathered during plant visits

Information obtained from state representatives

In any SIP revision, the attainment of the NAAQS through the application of a reasonable control strategy is the primary objective. This requires decisions concerning which specific sources should be controlled, based on a realistic comparison of the available control options. Comparison of control costs must consider both total annual costs and cost per ton of pollutant removed. The economic justification for recommended RACT controls relies heavily on such cost comparisons. Technical feasibility analysis takes into account the controls required in other states, plus information in technical publications and an assessment of site specific factors that could affect the technical feasibility of retrofitting and properly operating various technologies.

1.3 APPROACH TO DETERMINATION OF RACT

To satisfy the definition of RACT requires that controls retrofitted at an existing facility be as stringent as possible, yet both technologically and economically reasonable. Recommended RACT was determined by comparing control options in increasing order of stringency until the next control option was deemed infeasible for either economic or technical reasons. When the economic feasibility of a control option was subject to interpretation, more than one option was given, and the cost in dollars per ton of particulates removed was calculated for comparison by the user. In each case, PEDCo made a judgmental choice of which control option best represents RACT.

In general, the technological feasibility of a control was the first parameter ascertained. Once a control was deemed technologically feasible for retrofit, its economic feasibility was determined. If the control was judged to be both technologically and economically feasible, its efficiency was estimated, and an emission limitation was calculated based on this efficiency. Enforceability was weighed heavily in choosing the method of regulation. A control option that has a high cost in dollars per ton of pollutant removed may be included if it has a small capital cost.

Technological feasibility was based on the demonstration of these control technologies on an identical or similar emission source.

The economic feasibility of a control is less straightforward than its technological feasibility. The cost of retrofitting a control tends to be more plant-specific than the technological feasibility of the control; therefore, economic feasibility often must be determined on a case-by-case basis. Therefore, information gathered during plant visits was weighed heavily in determining economic feasibilities in this report.

PEDCo used the following general tests to determine whether a specific control could be considered RACT:

The control had a reasonable cost per ton of particulates removed.

The control had a low overall cost.

The control has generally been applied in the industry or within similar industries whether it was required by regulation or not.

The control was reasonable in total cost and was capable of meeting the most stringent regulations in Region IV and in the country.

Application of the control would contribute to the attainment of the NAAQS in the present nonattainment areas.

SECTION 2

PHOSPHATE PROCESS OPERATIONS

This section discusses the processes involved in the phosphate processing industry. It also discusses the emission sources, control options for these sources, costs of the control options, and recommended RACT. Each phosphate product is treated separately with subsections covering the following products:

Diammonium phosphate (DAP)
Monoammonium phosphate (MAP)
Granular triple superphosphate (GTSP)
Run-of-the-pile triple superphosphate (ROP/TSP)
Run-of-the-pile normal superphosphate (ROP/NSP)
Animal feed ingredients (AFI)

Also discussed in this section are RACT controls for phosphate rock dryers, phosphate rock grinding, loading railroad cars with phosphate rock, and loading ships with phosphate rock. The Appendix summarizes control and emissions data about the phosphate industry.

2.1 DIAMMONIUM PHOSPHATE

This subsection discusses the processes used in the production of DAP and the monoammonium phosphate formed in the DAP process and identifies the major particulate sources within each facility. The subsection also discusses the available control technology and the cost of a typical plant using this technology. From this analysis RACT recommendations are made.

2.1.1 Process Description

Ammonium phosphates are produced by reacting phosphoric acid with anhydrous ammonia. Diammonium phosphate production combines one mole of phosphoric acid with 2 moles of ammonia to yield a product having 21.2 percent nitrogen and 53.8 percent available phosphorus according to the reaction:

$$H_3PO_4 + 2NH_3 \rightarrow (NH_4)_2HPO_4$$

Fertilizers are identified by a three number combination that identifies the percent N, the percent P_2O_5, and the percent K_2O.[2] Typical compositions are between 11 - 48 - 0 and 18 - 46 - 0. Commercial ammonium phosphates are produced by two major processes: the TVA process (which uses a rotary drum mixer), and Dorr-Oliver process (which uses a pugmill ammoniator). Approximately 95 percent of the plants in the United States use the TVA process.

TVA Process--

Figure 2-1 is a process flow diagram of a TVA DAP granulation plant. Phosphoric acid is mixed in an acid mix tank with reagent (93 percent sulfuric acid). The mixed acids typically have a P_2O_5 content of 40 to 45 percent. The phosphoric acid used is a mixture of unconcentrated and concentrated wet process phosphoric acid.

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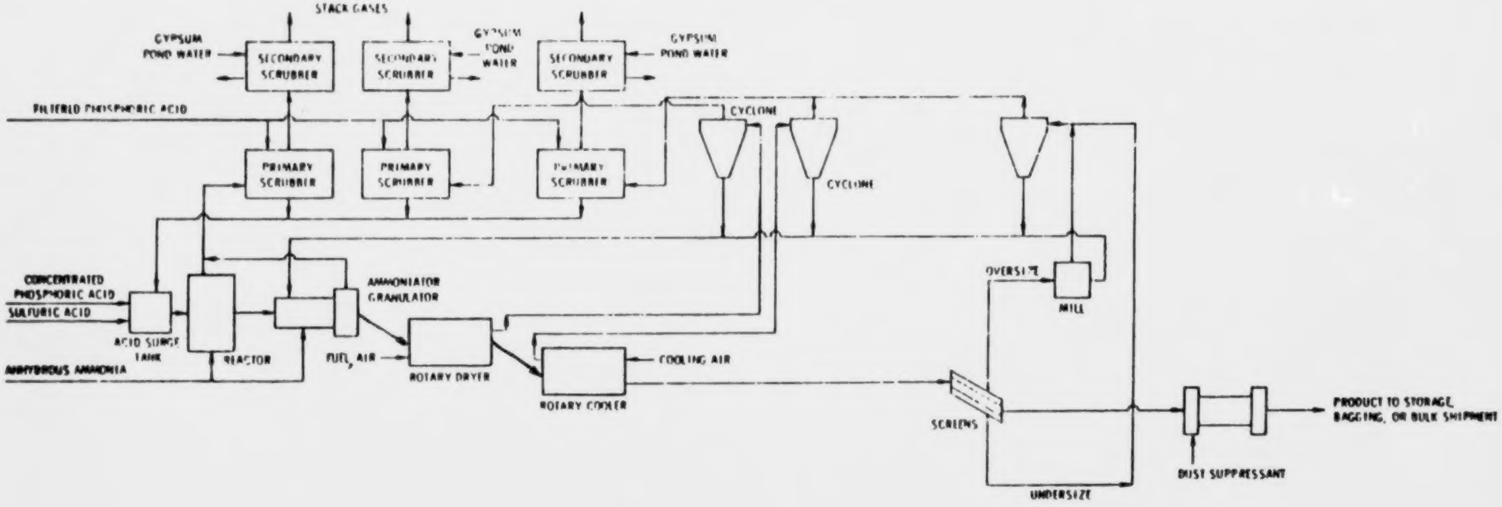

STACK GASES
GYPSUM POND WATER
SECONDARY SCRUBBER
SECONDARY SCRUBBER
GYPSUM POND WATER
SECONDARY SCRUBBER
GYPSUM POND WATER
FILTERED PHOSPHORIC ACID
CYCLONE
PRIMARY SCRUBBER
PRIMARY SCRUBBER
PRIMARY SCRUBBER
CYCLONE
CONCENTRATED PHOSPHORIC ACID
SULFURIC ACID
ANHYDROUS AMMONIA
ACID SURGE TANK
REACTOR
AMMONIATOR GRANULATOR
FUEL, AIR
ROTARY DRYER
ROTARY COOLER
COOLING AIR
OVERSIZE
MILL
SCREENS
UNDERSIZE
DUST SUPPRESSANT
PRODUCT TO STORAGE, BAGGING, OR BULK SHIPMENT

Figure 2-1. Process flow diagram of a TVA DAP plant.

The mixed acids are neutralized and premixed in a brick-lined acid reactor. Anhydrous gaseous or liquid ammonia is introduced with air and steam. The neutralization takes place at atmospheric pressure and the charge ratios (NH_3 to H_3PO_4 on a molar basis) are between 1.3:1.0 and 1.5:1.0. The heat of reaction is used to maintain the temperature of the slurry at 100° to 120°C. The heat allows the ammonium phosphate slurry to be concentrated by the evaporation of excess water and yet to maintain flow characteristics for pumping to the ammoniator granulator. The slurry at this temperature and molar composition is primarily monoammonium phosphate with a solids content of 78 to 82 percent. The reactor is vented by induced draft to reduce emissions of ammonia within the plant. Typical ventilation rates are between 2000 and 2500 scfm, but actual rates vary with reactor design and tightness. The tightness of a system can be improved by an effective operation/maintenance (O&M) plan. The reactor gases are scrubbed with a wet scrubber to remove the ammonia. Typical scrubber solutions are phosphoric acid (30 percent P_2O_5). The solubilized ammonium phosphate is recycled to the reactor.

The reactor slurry is pumped to the ammoniator-granulator, in which the formation of DAP is completed and the granular product is formed. The granulator consists of a rotary drum with retaining rings at each end and a scraper mounted inside the drum. A moving bed of recycled DAP fines are maintained in the drum at all times. Slurry from the reactor is sprayed on the recycled fine bed as ammonia is introduced under the bed. The final mixture reaches an ammonia phosphoric acid ratio between 1.8:1.0 and 2.0:1.0 (mole basis). The recycle fines are coated with slurry and grow by agglomeration. The product is withdrawn from the granulator as new fines are introduced. The recycle rate is highly variable, but typically is 2.5 to 4.0 lb/ton of product. The granulator is vented by induced draft to prevent the loss of ammonia within the plant. Typical ventilation rates are between 8,000 and 10,000 acfm. The ammoniation reaction in the granulator is exothermic, and the reactor is maintained between 85° and 105°C. The exhaust gases from the granulator contain ammonia not consumed in the reaction. The off-gases are typically scrubbed with a solution of phosphoric acid (30 percent P_2O_5). Ammonium phosphate is returned to the reactor as scrubber recycle.

Moist (plastic) DAP granules are transferred to a rotary oil- or gas-fired cocurrent flow dryer. In the dryer the moisture content of granules is reduced below 2 percent. Exhaust gases, which contain entrained particulates, are passed through a bank of simple cyclones to remove large particulate and then exhausted to a wet scrubber.

The temperature of the granular product at discharge from the dryer is between 82° and 104°C. The granules are elevated by bucket elevators and screened before cooling. The oversized materials are transferred to cage mills for size reduction, and the fines are recycled to the ammoniator-granulator.

The product is cooled in a rotary cooler to prevent caking and to reduce decomposition in storage. The cooler, screens, and handling equipment are ventilated, and exhaust gases are treated by a bank of simple cyclones. The exhaust gases are then treated by wet scrubbers.

The typical granule size of the product is between 1 and 4 mm. To prevent dusting in storage and transfer, some manufacturers treat the granules with lubricating oil (0.5 percent by weight). The granular DAP is placed in covered storage by overhead belt conveyors. The product is sold in bulk form or bagged.

Dorr-Oliver Process--

Figure 2-2 is a process flow diagram of a Dorr-Oliver DAP granulation plant. Phosphoric acid (24 to 36 percent P_2O_5) is fed to a series of agitated reactors in which reaction occurs with liquid or gaseous anhydrous ammonia. The reactants are transferred through a series of vessels in which the slurry increases in solids content and the pH is adjusted. The reactors are vented, and the off-gases are scrubbed with phosphoric acid (30 percent P_2O_5).

The ammonium phosphate slurry is transferred to a pugmill (blunger) in which recycled fines are added. The blunger contains parallel, counterrotating shafts with blades. The blades mix the slurry and recycle fines together to form grandules. The ratio of slurry to recycle is typically 6 to 12 lb/lb of product. The blunger is ventilated, and exhaust gases are treated with a scrubber.

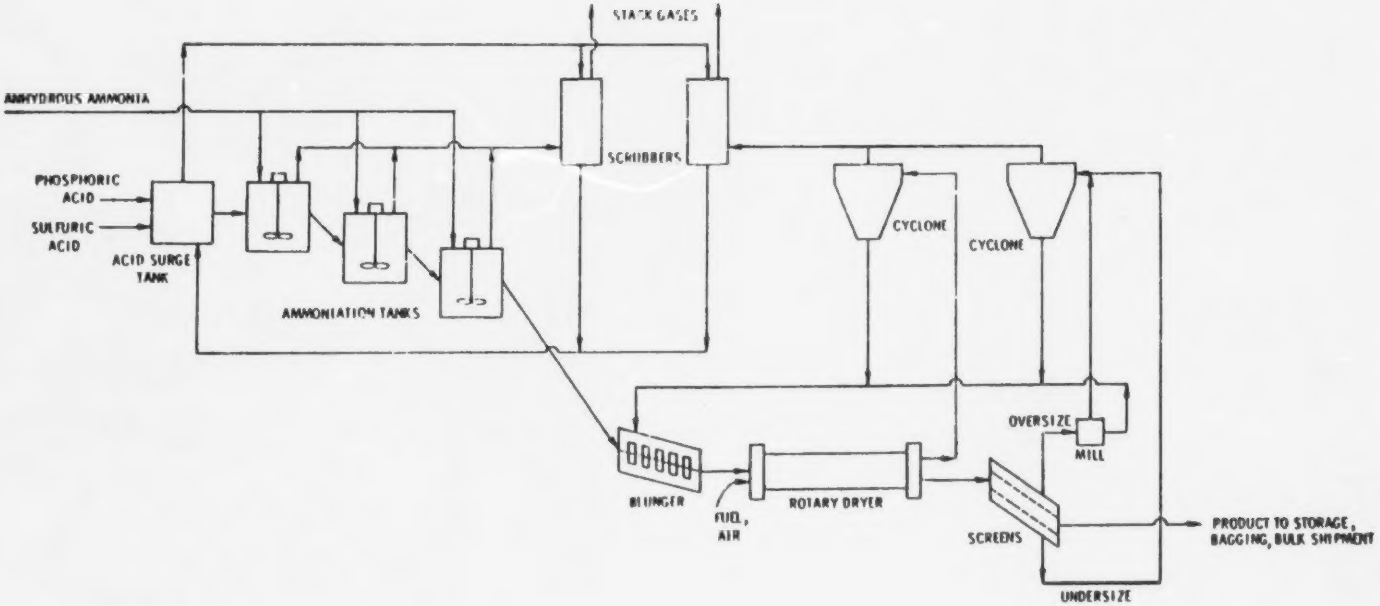

STACK GASES
ANHYDROUS AMMONIA
PHOSPHORIC ACID
SULFURIC ACID
ACID SURGE TANK
AMMONIATION TANKS
SCRUBBERS
CYCLONE
CYCLONE
OVERSIZE
MILL
BLUNGER
FUEL, AIR
ROTARY DRYER
SCREENS
PRODUCT TO STORAGE, BAGGING, BULK SHIPMENT
UNDERSIZE

Figure 2-2. Process flow diagram of a Dorr-Oliver DAP plant.

The product is transferred to a rotary, counterflow-fired dryer in which the moisture content is reduced to less than 2 percent. Exhaust gases from the dryer containing entrained particulates are passed through a bank of simple cyclones to remove large particulates and then exhausted to a wet scrubber. The granular product is elevated by bucket elevator to double-deck screens, and the oversize product is reduced in a cage mill. The undersized product is recycled to the blunger. The screens, mill, and transfer equipment are vented to simple cyclones and then to a wet scrubber. The granule size is typically between 2.4 and 1.7 mm. The product is shipped in bulk or bagged form.

Review of the processes operated in the phosphate producing area of central Florida indicated 11 facilities producing DAP by the two processes. The production rates of the lines are between 35 and 98 tons/h. Emission rates and control devices for these sources are listed in the Appendix.

2.1.2 Emission Sources and Control Options

A conventional DAP plant contains seven major points of particulate emissions:

(1) Reactor(s)
(2) Ammoniator-granulator (or blunger)
(3) Dryer
(4) Product screens
(5) Cooler
(6) Cage mills
(7) Elevators, belt conveyors, etc.

The volume of air required to prevent fugitive ammonia from being lost from the reactor(s) varies greatly from plant to plant and is typically included with exhaust from the ammoniator-granulator (or blunger). The gas volumes reported for single TVA process reactors range from 2000 to 2500 scfm at a temperature of 100° to 120°C. The ammoniator-granulator is exhausted at 8,000 to 10,000 acfm 85° 105°C. Gases from the reactors typically do not contain particulate and are vented to control ammonia only. The ammoniator-granulator contains particulate and ammonia emissions. The combining of these gas streams is accomplished to allow the recovery of ammonia in the gas stream. Typical loss from a TVA process reactor/ammoniator-granulator process is 30 lb of NH_3/ton of DAP product in a 50-ton/h facility. The entrained DAP dust from the ammoniator is roughly 27 lb/ton of product. The uncontrolled emission rates make it economically feasible to recover both ammonia and particulate for process recovery.

Without exception the preferred method of control in the plants surveyed is a venturi scrubber. The scrubbers are operated at a wide range of static pressure drop (ΔP) and liquor-to-gas ratios. Appropriate operating parameters should be specified in the O&M plan. The scrubbing solution is phosphoric acid (typically 30 percent P_2O_5). The wet particulates and ammonium phosphate formed from the acid/ammonia reaction in the scrubber are separated in cyclonic separator following the venturi. Typical static pressure drop observed was between 10 and 15 in. H_2O. The liquor-to-gas ratio was approximately 12 gal/1000 acfm. The venturi was followed by second-stage cyclonic spray scrubbers, packed beds, crossflow scrubbers, or a second venturi for final particulate control and fluoride control.

The dryer, which is used to remove moisture from the ammonium phosphate after granulation, is typically gas- or oil-fired. Heat inputs depend on moisture content of the granules and the product recycle ratio. Typical heat inputs are in the range of 500,000 Btu/ton of product. Particulate emissions from the dryer are controlled by a simple cyclone or bank of multiple cyclones followed by a venturi scrubber. The scrubber is typically followed by a cyclonic separator. Secondary collection is provided by a cyclonic spray scrubber, a crossflow scrubber, packed beds, or an additional venturi. Secondary collectors are used for fluoride control. The typical exhaust volume from the dryer is 65,000 acfm at 104°C, the typical static pressure drop in the venturi is 14 in. H_2O, and the typical liquor-to-gas ratio is 10 gal/acfm.

The product cooler is a rotary drum cooler, which allows the dried, screened granules to lose heat before being placed in storage. The motion of the granules (in a cooler equipped with flights) and of the air exhausted from the cooler results in rapid cooling of the product. The exhaust volume required for cooling is highly variable, depending on plant specification. Average values of the exhaust appear to be near 50,000 acfm. The exhaust is pretreated with a simple cyclone or bank of cyclones before being scrubbed. Scrubbers used are venturi, packed beds and wet cyclones. The venturi is typically followed by cyclonic spray scrubbers or crossflow scrubbers for secondary particulate collection or fluoride control.

Several systems were observed to use simple wet cyclones for particulate control. These systems were demonstrated to operate at an emission rate of 0.55 to 0.83 lb/ton of product.

The cage mills, elevator, conveyors, and transport equipment generate fugitive particulate emissions. These emissions are ventilated at elevator heads, transfer points, screen head space, and cage mills. The ventilation rate varies from plant to plant, depending on age, tightness, and number of transfer points. Emissions from these sources are controlled by simple cyclones or banks of simple cyclones with recycle to granulator and are followed by a scrubber. The scrubber is typically a venturi followed by a packed bed, crossflow scrubber, or cyclonic spray scrubber.

A summary of control options used in central Florida is presented in Table 2-1. Because of the large number of combinations of control equipment used, stack test data do not indicate control efficiency at individual process sources. The major sources are controlled by venturi scrubbers with each exhaust discharged to a common tail gas scrubber or common stack. The uniqueness of each plant makes testing of each subprocess component impractical. The most reasonable method of emission measurement appears to be applying a mass emission rate to the common exhaust or summing mass emissions from each exhaust.

TABLE 2-1. PARTICULATE EMISSION SOURCES AND CONTROL OPTIONS FOR DAP PLANTS

Source	Control option
Reactor, granulator/blunger	Venturi/crossflow, venturi/packed bed, venturi/cyclonic spray, packed bed/crossflow
Dryer	Venturi/crossflow, venturi/packed bed, venturi/cyclonic spray, packed bed/crossflow
Screens, cooler, cage mills, conveyors	Venturi/crossflow, venturi/spray cyclone, packed bed/crossflow, wet cyclone

A review of stack test data on the 11 process lines indicated total controlled plant emission rates of 0.11 to 0.95 lb/ton of product. Grouping of emission sources by control system type indicates that the lowest emission rate is achieved with a medium-energy venturis followed by crossflow scrubbers at high liquid-to-gas ratios or packed bed scrubbers followed by crossflow scrubbers. The highest emission rates occur at plants using wet cyclones or cyclonic spray scrubbers. Controlled rates at plants using medium-energy venturis followed by crossflow scrubbers range from 0.19 to 0.54 lb/ton. The controlled emission rate from systems using packed bed scrubbers followed by crossflow scrubbers is between 0.11 and 0.31 lb/ton. Systems using combinations of controls (e.g., venturis, spray cyclonic scrubbers, and wet cyclones) have controlled emission rates between 0.64 and 0.95 lb/ton. Data for specific plants are given in the Appendix.

To ensure that the control equipment emission rates truly reflect plant emissions requires complete efficient capture of emissions from sources within the plant. The installation and operation of enclosures, hoods, and ventilation systems in conjunction with an O&M plan have been demonstrated to reduce fugitive losses effectively within the manufacturing plant. The maintenance of these systems has been demonstrated to be a major problem in reducing emissions. To ensure good operating practices requires establishing an effective method of evaluating loss to the ambient atmosphere. An opacity standard applied to fugitive loss from the building is an effective method of maintaining control of fugitive emissions. Plants using good capture practices can reasonably be expected to reduce fugitive losses from building vents to less than 5 percent opacity.

2.1.3 Control Costs

An estimate of the cost of the various control options discussed in the previous subsection is presented in Table 2-2. The cost and emission estimates are based on a typical plant producing 50 tons of DAP/h by the TVA process. The air volumes, temperatures, and uncontrolled emission rates are based on mass balances provided by the phosphate industry. The material of construction is stainless steel. The scrubber pressure drop, liquor rates, and fan horsepower are typical of the plants surveyed. The capital cost is based on the values reported on permit applications on file with the State of Florida Department of Environmental Regulation, Tampa, Florida. The capital costs have been adjusted to January 1980 dollars by use of the Chemical Engineering (C-E) Plant Cost index.[3] Because of the wide range of plant layout and design, number of vendors available to supply components, and degree of safety factor and redundancy designed into individual plants, capital cost may vary by ± 50 percent. The cited examples are those for which more current data were available (i.e., examples typical of current technology).

Figure 2-3 shows the control system arrangement and process parameters for the first option in Table 2-2. The cost analysis includes the total capital cost of the venturi and tail gas

TABLE 2-2. CONTROL COSTS OF A TYPICAL DAP PLANT[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Reactor, dryer, granulator, cooler, equipment vents	(3) Venturi/ cross-flow	99.37-99.77	85.9	0.19-0.54	17,180	1,724,000	10	280,581	471,937	3,178,300	(141)
Reactor, dryer, granulator, cooler, equipment vents	(2) Venturi/ spray cyclonic plus (2) wet cyclone	98.90-99.25	85.9	0.64-0.94	16,992	1,302,000	10	211,914	345,024	3,143,520	(152)

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

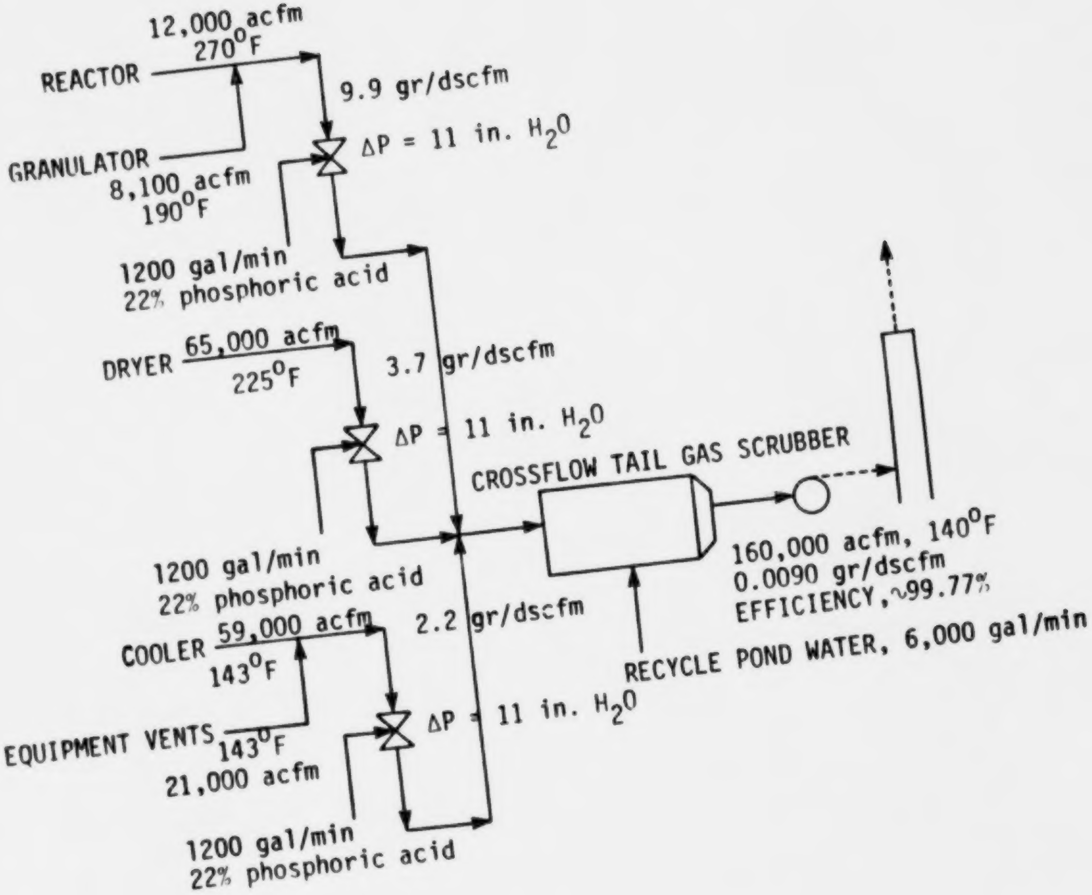

12,000 acfm
270°F
REACTOR
GRANULATOR
8,100 acfm
190°F
9.9 gr/dscfm
ΔP = 11 in. H2O
1200 gal/min
22% phosphoric acid
DRYER
65,000 acfm
225°F
3.7 gr/dscfm
ΔP = 11 in. H2O
CROSSFLOW TAIL GAS SCRUBBER
1200 gal/min
22% phosphoric acid
160,000 acfm, 140°F
0.0090 gr/dscfm
EFFICIENCY, ~99.77%
COOLER
59,000 acfm
143°F
2.2 gr/dscfm
RECYCLE POND WATER, 6,000 gal/min
EQUIPMENT VENTS
143°F
21,000 acfm
ΔP = 11 in. H2O
1200 gal/min
22% phosphoric acid

Figure 2-3. Process flow diagram of a typical 50 ton/h DAP plant using three venturi scrubbers and a crossflow tail gas scrubber.

scrubber. Utilities are computed for the total system gas volume and resistance. The water flow requirements are based on venturi plus tail gas scrubber.

The second control system option in Table 2-2 is based on a system using two venturi scrubbers with cyclonic separators followed by a spray tail gas scrubber. The product cooler is controlled by twin wet cyclones. The utilities are based on total gas volume and water flow rates for the system. The design volumes and production rates are not ideally matched to those in the first option; therefore, the costs are not as comparable as desired.

The capital cost may vary ± 30 percent. The uncontrolled emission factor is based on 85.9 lb/ton product loss from all sources within the complex. This PEDCo estimate compares with 82 lb/ton estimated in AP-42.[6] The controlled emission rate is based on the range of controlled rates gathered from stack test on file with the Florida Department of Environmental Regulation (DER). The collected particulate rate is based on a maximum production rate of 50 tons/h for 8000 h/yr. The annualized cost is also based on 8000 hours of production.

The recovered product in the scrubbers is considered valuable and is typically returned to the processes in reactors or granulators. If it is assumed that the solids collected are composed of diammonium phosphate and the material is totally recoverable, the credit for recycle is $3,143,000/yr, assuming a value of $185/ton based on market value of the product.

Applying the credit for product recovery to the first control system option yields a net cost savings of $141/ton.

The cost of operation of the second option is less than the first, but inclusion of the recovered product credit yields a net operating credit of $152/ton removed (i.e., a net savings). In practice scrubbers are a necessary product recovery portion of the process and actually decrease the cost of manufacture.

2.1.4 Recommended RACT

From the standpoint of technical feasibility, a combination of control devices (venturi scrubbers, cyclonic spray scrubbers and crossflow or packed bed scrubbers) can achieve emission levels in the range of 0.30 lb/ton of product. The use of low-energy wet cyclones clearly results in higher controlled emission rates. The variation in plant design and scrubber arrangement does not allow the selection of one combination of control system components or the selection of operating conditions that can achieve this recommended level of emissions. Stack test data indicate that at least a medium- to high-energy primary scrubber is required.

The cost of using the lower-energy scrubber (wet cyclone) as compared with the higher-energy venturi is not clearly defined because capital cost is only available for plants using a venturi in combination with wet cyclones. Because of the highly site-specific nature of each device and control system, it was not considered advisable to reduce the analysis to a subprocess/control system level. In either case it was observed that the primary scrubbers were used for product recovery and that the credit from recovered product was greater than the annualized cost of systems.

A fugitive emission limit applied to the plant process building is recommended to ensure that the emissions measured by the stack test represent the controlled emission level. The fugitive emission level is based on the opacity of material escaping the building. Based on good maintenance and good hood capture efficiency, a 5 percent opacity limit is recommended.

The test method to be used for determining the mass emission standard should be U.S. Environmental Protection Agency (EPA) Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of the solubilization of the diammonium phosphate on the filter when collected below the moisture dewpoint. Opacity should be determined by EPA Method 9.[5]

2.2 MONOAMMONIUM PHOSPHATE

This subsection discusses the processes used in the production of MAP by the spray tower process and identifies the major particulate sources from the process area. Also, it discusses the available control technology and the cost of using this technology. Based on this analysis, RACT recommendations are made.

2.2.1 Process Description

Ammonium phosphate is produced by the combination of phosphoric acid and ammonia to form MAP by the reaction:

$$H_3PO_4 + NH_3 \rightarrow NH_4H_2PO_4$$

The process used to produce the product involves the reaction of the ammonia and acid in a jet spray nozzle under pressure. The reaction product emerging from the reactor consists of molten MAP suspended in a high-velocity steam jet. Suspended MAP solidifies into tiny, round, porous particles, and steam and hot air are exhausted from the enclosure from the top counterflow to the falling product. The product is collected in a dry state at the bottom of the enclosure (Prill Tower) and removed by rotating rakes onto conveyors for transfer to a product cooler and to storage. Figure 2-4 shows the Prill Tower method of producing MAP.

The formation of the product occurs in the jet nozzle reactor as the anhydrous ammonia flashes to gas in the presence of the liquid phosphoric acid. Figure 2-5 shows the jet nozzle reactor used to produce MAP. The MAP begins to form at the tip of the inner nozzle and exits the outer cone at 500 miles/h. The acid used in the process is wet process phosphoric acid (52 percent P_2O_5). The ammonia injection pressure is typically 120 psig. The particulate emissions from the cooler and spray tower are typically exhausted to a scrubber.

Review of the process operated in the central Florida phosphate producing area indicated two facilities producing MAP by this process. The production rates were 14 and 25 ton/h.

2.2.2 Emission Sources and Control Options

In the manufacture of MAP by use of a jet nozzle reactor and Prill Tower, there are typically two sources of particulate

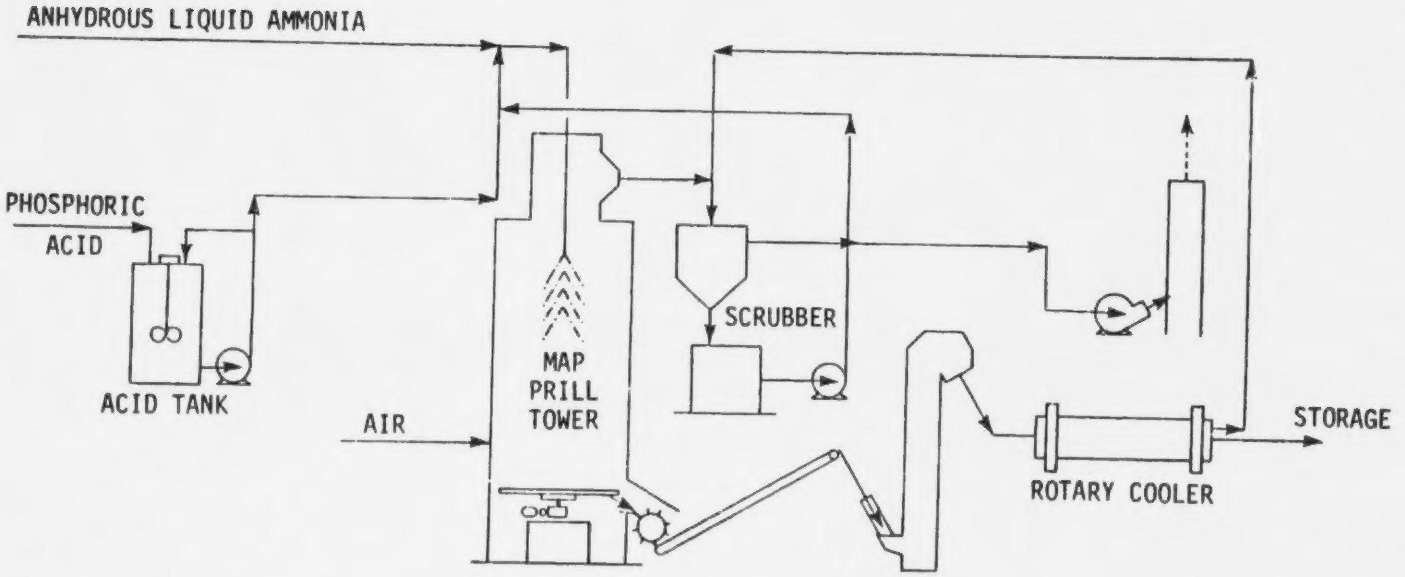

ANHYDROUS LIQUID AMMONIA
PHOSPHORIC ACID
ACID TANK
AIR
MAP PRILL TOWER
SCRUBBER
ROTARY COOLER
STORAGE

Figure 2-4. Process flow diagram of a plant producing MAP with a Prill Tower.

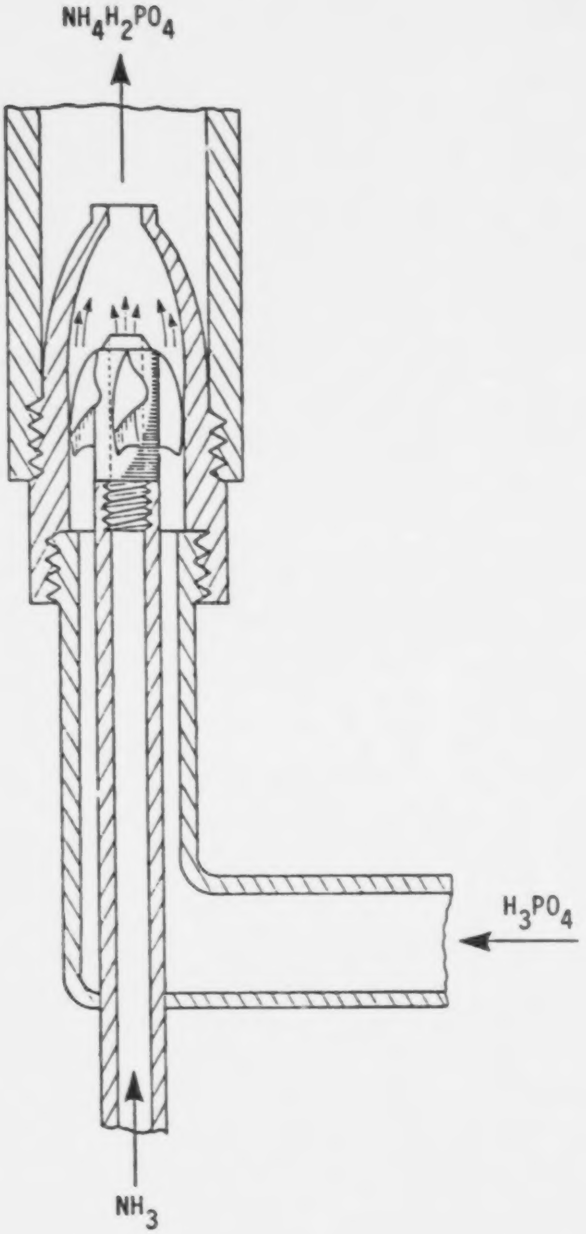

$NH_4H_2PO_4$
H_3PO_4
NH_3

Figure 2-5. Jet nozzle reactor used to produce MAP.

emissions: the Prill Tower and rotary cooler.

The exhaust from the Prill Tower contains ammonia, moisture, and fine particles of ammonium phosphate. The volume of gas is dependent on the nozzle design and tower cross-sectional area. Towers producing fine granules (powder) use less gas volume to reduce entrainment of product. There is a minimum volume necessary to remove heat and moisture and allow the MAP particles to solidify. Of the two plants studied, one combined the Prill Tower and cooler exhausts into a single scrubber, and the other did not use a cooler. The gas volumes of the two control systems were 19,000 and 62,000 acfm, and the process weights were 14 and 25 ton/h. The control devices used in both facilities were combinations of venturi scrubbers and crossflow scrubbers. The controlled emission rates were 0.12 and to 0.19 lb/ton.

The use of venturi scrubbers is an accepted method of controlling particulate emissions. The tail gas scrubber is primarily intended to control fluorides. No data are available concerning particle size distribution or uncontrolled emission rate from the Prill Tower or cooler. Without this data, it is not possible to predict accurately the control efficiency of other control option combinations. It is probable that cyclonic spray scrubbers can also be used. Fugitive dust does not appear to be a problem in this process because of minimal material transport. Emission sources and control options are presented in Table 2-3.

TABLE 2-3. PARTICULATE EMISSION SOURCES AND CONTROL OPTIONS FOR MAP PLANTS

Source	Control option
Prill Tower, rotary cooler	Venturi/crossflow, venturi/cyclonic spray, venturi/packed bed

2.2.3 Control Costs

An estimate of the cost of the control method discussed in the previous subsection is presented in Table 2-4. The cost and emission estimates are based on a theoretical plant producing monammonium phosphate at 25 tons/h with a jet nozzle and Prill Tower. The uncontrolled emission rate is based on data for an ammonium nitrate Prill Tower, because specific data on monoammonium phosphate are unavailable.

The capital cost is estimated from data filed with the State of Florida DER. The cost of operation is based on total system pressure drop and water requirements.

Figure 2-6 presents the control system arrangement for the control option.

The uncontrolled emission rate is estimated to be 20 lb/ton of product. The controlled emission rate is based on stack test data filed with the Florida DER. The maximum production rate is 25 tons/h at 8000 h/yr.

The recovered product is returned to the process for recovery. The value of MAP phosphate is $205/ton. If the recovered product is returned to the process and credited, the annualized cost is $84/ton recovered.

TABLE 2-4. CONTROL COSTS OF A TYPICAL MAP PLANT[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Prill tower cooler	Venturi/ cross-flow	99-99.4	20	0.12-0.19	1981	409,836	10	66,700	172,599	406,105	(84)

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

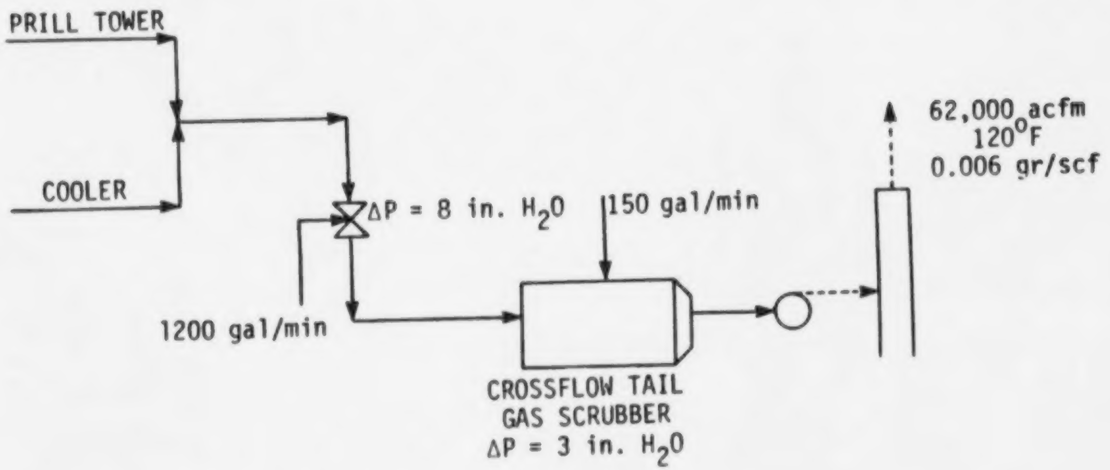

PRILL TOWER
COOLER
ΔP = 8 in. H2O
1200 gal/min
150 gal/min
CROSSFLOW TAIL GAS SCRUBBER ΔP = 3 in. H2O
62,000 acfm
120°F
0.006 gr/scf

Figure 2-6. Process flow diagram of typical MAP plant using venturi scrubber and crossflow tail gas scrubber.

2.2.4 Recommended RACT

From the standpoint of achievable emission reduction, a combination of control methods (venturi scrubbers and crossflow scrubbers) can achieve emission levels in the range of 0.20 lb/ton of product.

The cost of control is not considered critical because the range of control options is not wide and the recovered product has a value of $205/ton.

2.3 GRANULAR TRIPLE SUPER PHOSPHATE

This subsection discusses the processes used in the production of GTSP and identifies the major particulate sources within each facility. The subsection also discusses the available control technology and cost of a typical plant using this technology. Based on this analysis, RACT recommendations are made.

2.3.1 Process Description

Phosphate rock is composed of phosphate in the form of the mineral fluorapatite $[Ca_3(PO_4)_2]_3 \cdot CaF_2$. The phosphate in this form is only slightly soluble and thus unsuitable for modern agriculture. The phosphate is made available as a plant food by reacting the phosphate rock with phosphoric acid by the following reaction:

$$\underset{\text{Fluorapatite}}{[Ca_3(PO_4)_2]_3 \cdot CaF_2} + 14\ \underset{\text{phosphoric acid}}{H_3PO_4} + 10\ \underset{\text{water}}{H_2O}$$

$$\rightarrow 10\ \underset{\text{monocalcium phosphate monohydrate}}{[CaH_4(PO_4)_2 \cdot H_2O]} + \underset{\text{hydrogen fluoride}}{HF}$$

The monocalcium phosphate is commonly referred to as a triple super phosphate (TSP) and contains between 45 and 49 percent P_2O_5. The granular form of TSP improves its storage and handling properties. A granule between 1 and 4 mm in diameter is produced by one of two processes: granulation of ROP-TSP and direct granulation of TSP slurry.

Basic GTSP Process--

Two methods are used for the direct production of GTSP: the Dorr-Oliver slurry granulation process and the TVA one-step granulation process. The TVA process is not used for general commercial production and is not considered in this study. Figure 2-7 is a process flow diagram of the Dorr-Oliver process.

In the Dorr-Oliver process, phosphate rock is ground to a fineness between 75 μm and 150 μm and is charged to a reactor with phosphoric acid (40 percent P_2O_5). The rock and acid are reacted for 1 to 2 hours until a slurry is produced. The slurry is pumped from the reactor tanks and sprayed onto a bed of dry recycled GTSP fines in a rotary granulator. In the granulator the slurry builds up on the fines by coating and agglomeration.

In some process variations, pugmills are used instead of granulators. A pugmill is composed of a V-shaped trough containing twin counterrotating shafts with blades. The shearing, mixing, and kneading action of the mill agglomerates the slurry into granules.

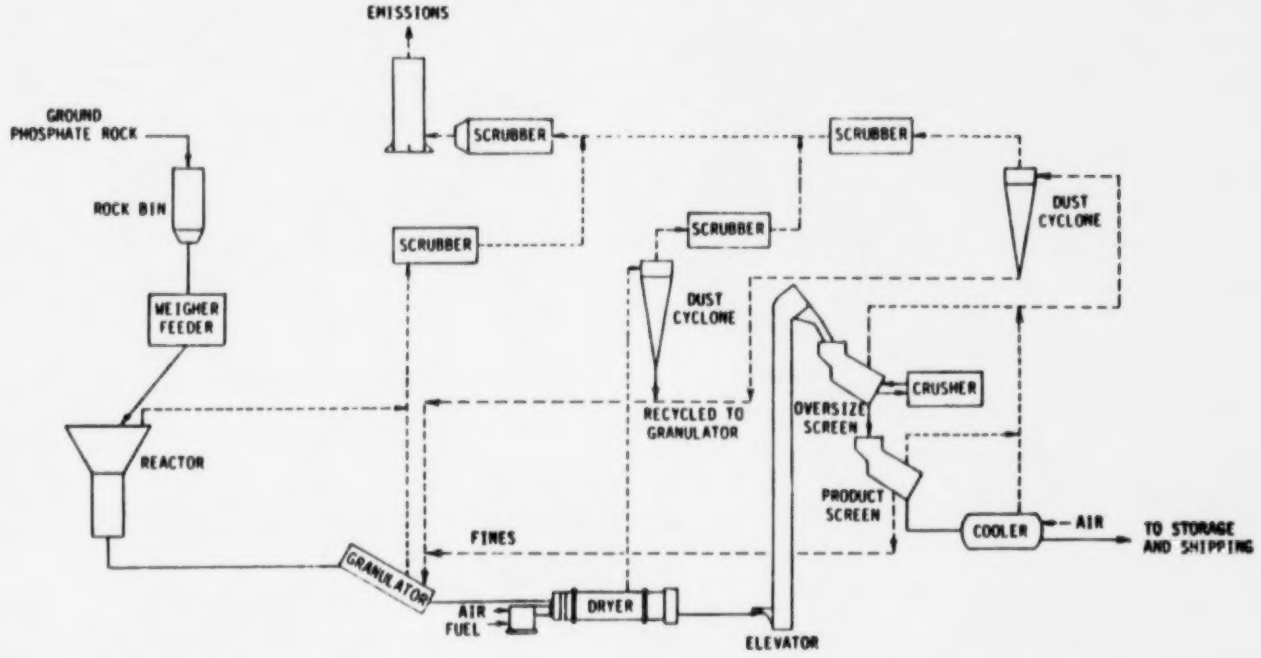

EMISSIONS
GROUND PHOSPHATE ROCK
ROCK BIN
WEIGHER FEEDER
REACTOR
SCRUBBER
SCRUBBER
SCRUBBER
SCRUBBER
DUST CYCLONE
DUST CYCLONE
RECYCLED TO GRANULATOR
CRUSHER
OVERSIZE SCREEN
PRODUCT SCREEN
COOLER
AIR
TO STORAGE AND SHIPPING
FINES
GRANULATOR
AIR
FUEL
DRYER
ELEVATOR

Figure 2-7. Process flow diagram of a Dorr-Oliver slurry granulation plant.

The rotary drum granulator consists of an open-end, rotary cylinder with retaining rings at each end. The rotary drum contains a fixed scrapper mounted inside the drum to remove material from the wall. A bed of recycled GTSP is maintained in the granulator, and the liquid slurry is introduced through distributor pipes set under the bed.

Wet granules from the granulator (or pugmill) are discharged into a rotary direct-fired gas or oil dryer, where the excess water is evaporated and the chemical reaction of the acid accelerated by heat. Dried granules are elevated by bucket elevators and screened through double-deck screens. The oversized materials are reduced in chain mills, and the fines are returned to the granulator.

Granules produced by this process are between 1 and 4 mm in diameter and are cooled in a rotary drum cooler. The product is then placed in storage for curing. The typical curing period is between 3 and 5 days. The product is then screened, bagged, and shipped.

The reactor (pugmill), dryer, cooler, chain mills, screens, and transfer equipment are ventilated and controlled by simple cyclones and scrubbers.

GTSP from ROP/TSP--

In this process, ROP/TSP is removed from storage and reduced in size by pulverizers. The product is screened, and the material is introduced into a rotary granulator. Steam and water are introduced to the granulator to wet the product and aid in agglomeration. Granules are dried in a rotary gas- or oil-fired dryer to produce a hard product. The product is screened, and the fines recycled to the granulator.

The product is placed in storage for bagging and shipping. The pulverizers, screens, granulators, and dryer are ventilated, and particulate emissions are controlled by simple cyclones and scrubbers.

Review of the processes operated in the central Florida phosphate producing area indicated six facilities producing GTSP by the two processes. Emissions and controls for five of these facilities is given in the Appendix. The production rates of the lines were between 31 and 72 tons/h.

2.3.2 Emission Sources and Control Options

The seven major points of particulate emissions in a conventional GTSP production plant are listed below:

(1) Reactor
(2) Granulator/blunger
(3) Dryer
(4) Product screens
(5) Cooler
(6) Mills/crushers
(7) Elevators, belt conveyor, etc.

The volume of air required to collect fugitive emissions from the reactor(s) varies from plant to plant and is included with other sources in the plant. The primary emissions from the reactor are fugitive particulates during rock charging and fluorides released by the reaction. Rates of 4000 acfm at 150°F have been indicated at some facilities. Uncontrolled emission rates of up to 10 lb/ton of product have been estimated.

The granulator/blunger is normally ventilated to reduce or remove heat and hydrogen fluoride generated in the continued reaction and granulation process. Typical gas volume of a 42-ton/h product granulator with a recycle ratio of eight to one is approximately 12,000 acfm at 130°F. The estimated rate of emissions from the granulator is 21 lb/ton of product. Control of the reactor and granulator/blunger is typically accomplished by a venturi scrubber followed by a crossflow or packed bed scrubber.

The granulated GTSP is dried in a rotary dryer fired with propane, natural gas, or light fuel oil. The heat input is in the range of 700,000 Btu/ton of product. The particulates are exhausted from the dryer and collected for recycle in cyclones. The exhaust rate at a typical 42-ton/h plant is 46,000 acfm at 220°F. The uncontrolled emission rate, after fines recovery in the process cyclone, is 16 lb/ton of product. Particulates are typically controlled by venturi scrubbers followed by packed bed or crossflow scrubbers.

The product is screened, with oversize crushed and placed in storage. In some plants a cooler is included before the product is placed in storage. A typical rate of exhaust from the cooler is 50,000 acfm. The elevators, conveyors, and screens are ventilated, and the product is recovered in simple cyclones. Exhaust rates from these sources depend on plant size, layout, and tightness and are typically 20,000 acfm. Uncontrolled emissions from the product recovery cyclone serving the material handling and conveying areas are estimated at 8 lb/ton. Typical particulate control methods include venturi scrubbers followed by either packed bed scrubbers or crossflow scrubbers.

Because of the combinations of process vents and control devices, it is not possible to develop a source-by-source control device emission characterization; however, a combined plant emission evaluation has been made. The controlled emission rate from all sources at six facilities is in the range of 0.07 to 0.37 lb/ton of GTSP produced. The highest rate was at a facility using packed bed scrubbers (0.37 lb/ton). The lowest rate was at a facility using a venturi scrubber followed by packed bed scrubber (0.07 lb/ton). Facilities using various combinations of venturi, packed bed, and crossflow scrubbers account for the midrange data.

To ensure that the control equipment emission rate truly reflects the plant emissions requires complete and efficient capture of emissions from sources within the plant. The installation and operation of enclosures, hoods, and ventilation systems have been demonstrated to reduce fugitive losses effectively within the manufacturing area. To ensure that these systems are properly maintained and that emissions do not bypass the control equipment requires a method of evaluating capture effectiveness.

It appears that an opacity standard applied to fugitive losses from the building is an effective method of maintaining control of fugitive emissions. Plants with good system design and maintenance ensured by a good O&M plan can reasonably be expected to maintain fugitive losses from building vents to less than 5 percent opacity. Table 2-5 presents particulate emission sources and control options for GTSP plants.

2.3.3 Control Costs

An estimate of the cost of the various control options discussed in the previous subsection is presented in Table 2-6. The cost and emission estimates are based on a theoretical GTSP plant producing between 62 and 72 tons/h of GTSP by the Dorr-Oliver Process. The air volumes, temperatures, and uncontrolled emission rates are based on mass balances provided by the phosphate industry. The material of construction is assumed to be stainless steel. The scrubber pressure drop, liquor rates, and fan horsepower are typical of plants surveyed. The capital cost is based on the values reported on permit applications on file with the State of Florida Department of Environmental Regulation, Tampa, Florida. The capital costs have been adjusted to January 1980 dollars by use of the C-E plant cost index[3]. Because of the wide range of plant designs, vendor specifications, and equipment ages, the capital cost may be in error by ± 50 percent. The cited examples are those cases in which process weight, gas volume, and design are comparable. The examples are also based on the limited capital data available.

TABLE 2-5. PARTICULATE EMISSION SOURCES AND CONTROL OPTIONS FOR GTSP PLANTS

Source	Control option
Reactor, granulator/blunger	Venturi/crossflow, venturi/packed bed, venturi/cyclonic spray/crossflow
Dryer	Venturi, venturi/crossflow, venturi/cyclonic spray/crossflow
Screens, cooler, cage mills, conveyors,	Venturi, venturi/crossflow, venturi/cyclonic spray crossflow
Storage, shipping	Venturi, packed bed

TABLE 2-6. CONTROL COSTS OF A TYPICAL GTSP PLANT[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Reactors, granulators, dryer, equipment vents	Venturi/ tail gas	99.70	55.7	0.17	13,771[a]	956,284	10	155,635	336,456	2,065,650	(114)
Reactors, granulators, dryer equipment vents	Venturi/ cyclonic spray	99.73	55.7	0.15	15,998[b]	977,272	10	159,051	289,601	2,399,700	(121)

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Process weight of 62 tons/h.

[d] Process weight of 72 tons/h.

Figure 2-8 shows the control system arrangement for the venturi and tail gas scrubber option. The cost analysis includes the total capital cost for the venturi and tail gas scrubber. Utility costs are computed for the total gas volume and resistance. The water flow rate is based on venturi and tail gas scrubber air flow rates.

The second control system option is based on a system using a venturi scrubber with a cyclonic spray scrubber for fluoride control. The utilities are computed assuming a pressure drop of 12 in. H_2O and a water rate of 15 gal/1000 acfm. The process rates of the two systems are not matched, but exhaust gas volumes are comparable.

The uncontrolled emission rate estimated by PEDCo is based on an emission factor of 55.7 lb/ton. The controlled emission rate is based on stack test data on file with the State Agency.

The particulate removal rate is computed based on the emission factor and a production rate of 62 and 72 ton/h for 8000 h/yr.

The recovered product in the scrubbers (venturi) is returned to the process as makeup to the reactors. The value of GTSP is $150/ton. If this credit is applied to annualized cost of operating the systems, the scrubbers have a net profit of $114 to $121/ton removed. The scrubbers in practice are necessary process recovery devices that decrease the cost of manufacture.

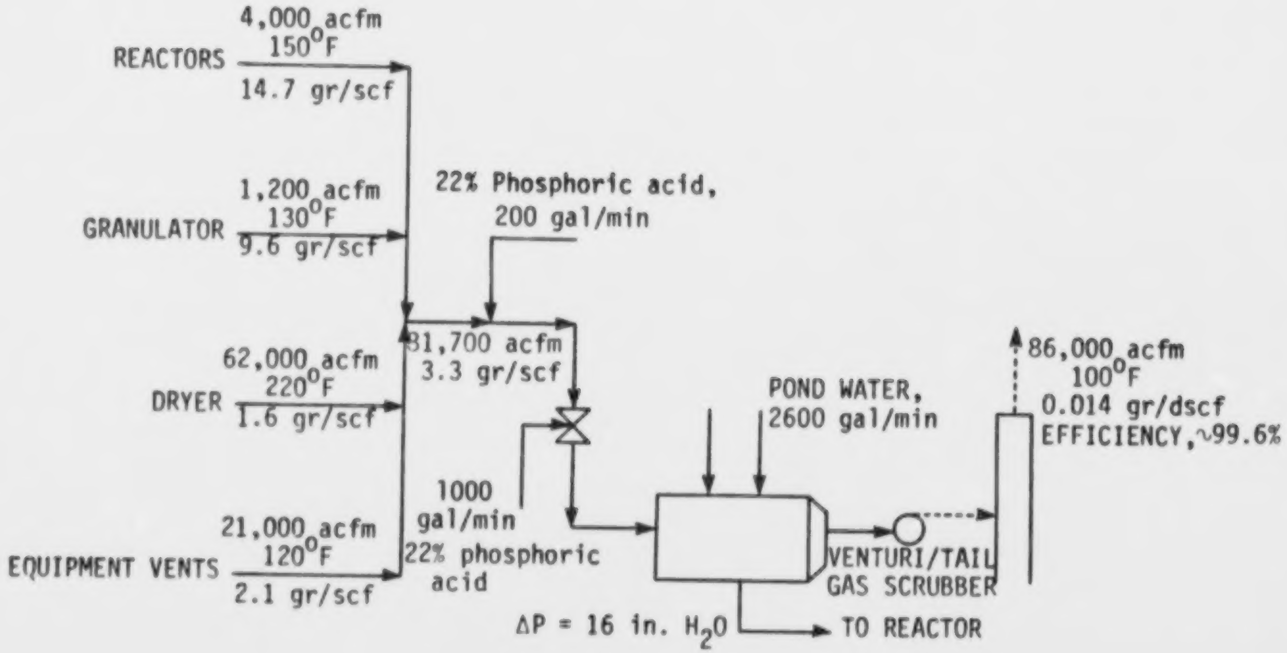

REACTORS
4,000 acfm
150°F
14.7 gr/scf
GRANULATOR
1,200 acfm
130°F
9.6 gr/scf
DRYER
62,000 acfm
220°F
1.6 gr/scf
EQUIPMENT VENTS
21,000 acfm
120°F
2.1 gr/scf
22% Phosphoric acid, 200 gal/min
81,700 acfm
3.3 gr/scf
1000 gal/min
22% phosphoric acid
POND WATER, 2600 gal/min
VENTURI/TAIL GAS SCRUBBER
ΔP = 16 in. H2O
TO REACTOR
86,000 acfm
100°F
0.014 gr/dscf
EFFICIENCY, ∼99.6%

Figure 2-8. Process flow diagram of a typical GTSP plant using venturi scrubber and crossflow tail gas scrubber.

2.3.4 Recommended RACT

From the technological standpoint, combinations of control devices (venturis, cyclonic spray scrubbers, and tail gas crossflow scrubbers) can achieve an emission rate of 0.20 lb/ton of product. Based on the cost of a venturi/crossflow scrubber and venturi/spray cyclonic scrubber and the credit for recovered product, option costs are not significantly different.

To ensure that the measured emission rate from the control device represents the true emission level requires efficient and complete capture of the emissions at the source. A fugitive emission standard is recommended to maintain this level of control. With the use of well-designed enclosures and hoods and proper maintenance, the facilities can achieve and maintain a level of uncontrolled (fugitive) emissions below an observed opacity of 5 percent at the building vent.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of the solubilization of the diammonium phosphate on the filter when collected below the moisture dewpoint. Opacity should be measured using EPA Method 9.[5]

2.4 RUN-OF-THE-PILE TRIPLE SUPER PHOSPHATE

This subsection discusses the processes used in the production of ROP/TSP and identifies the major particulate sources within each facility. The subsection also discusses available control technology and cost of employing this technology. Based on this analysis, RACT recommendations are made.

2.4.1 Process Description

Run-of-the-pile triple super phosphate is produced by the chemical reaction of phosphoric acid with phosphate rock. The rock is converted from insoluble fluorapatite to soluble monocalcium phosphate monohydrate. The reaction is the same as that shown in Subsection 2.3.1. The differences between the two methods are the physical appearance of the products and the time required for completion of the chemical reaction.

In the ROP/TSP process, ground phosphate rock is mixed with phosphoric acid (50 to 54 percent P_2O_5) in a pan or cone mixer. In the cone mixer, the rock is placed in contact with the acid by tangential flow of acid. The mixing forms a slurry of super phosphate, which is discharged from the cone into a moving belt. The slurry on discharge from the mixer begins to become plastic and solidifies as it moves down the belt. The belt is referred to as the den, and the super phosphate hardens as it moves down the belt. The action of the acid on the fluoropatite releases hydrogen fluoride, and the solidifying mass (matrix) becomes porous. Some facilities use mixers or pugmills to mix the solidifying mass, release the trapped gases, and reduce curing time. The matrix at the end of the solidifying process has the appearance of a honeycomb.

The matrix at the end of the curing belt is not completely cured (i.e., (chemical reactions are not completed). This material is placed in storage for 3 to 5 weeks in the curing building. The matrix is broken or cut at discharge from the belt before complete solidification occurs. Some plants pass the coarse ROP/TSP through a rotary dryer to increase the chemical reaction rate before placement of the product in storage. The heat reduces the curing time required before shipment. The cured ROP/TSP product commonly is crushed and screened in the storage area before shipping.

The cone mixer, den, dryer, and curing building are ventilated, and particulate and gaseous emissions are collected in scrubbers. Review of the processes in the central Florida phosphate producing area indicated six facilities producing ROP/TSP. The production rates of the lines were between 18 and 48 ton/h. Figure 2-9 is a process flow diagram of a typical ROP/TSP plant.

2.4.2 Emission Sources and Control Options

The four major points of particulate emissions in a conventional ROP/TSP plant are listed below:

(1) Cone mixer
(2) Den/curing belt
(3) Dryer (optional)
(4) Curing building

The cone mixer represents the point of contact between the phosphoric acid and ground phosphate rock. The typical gas

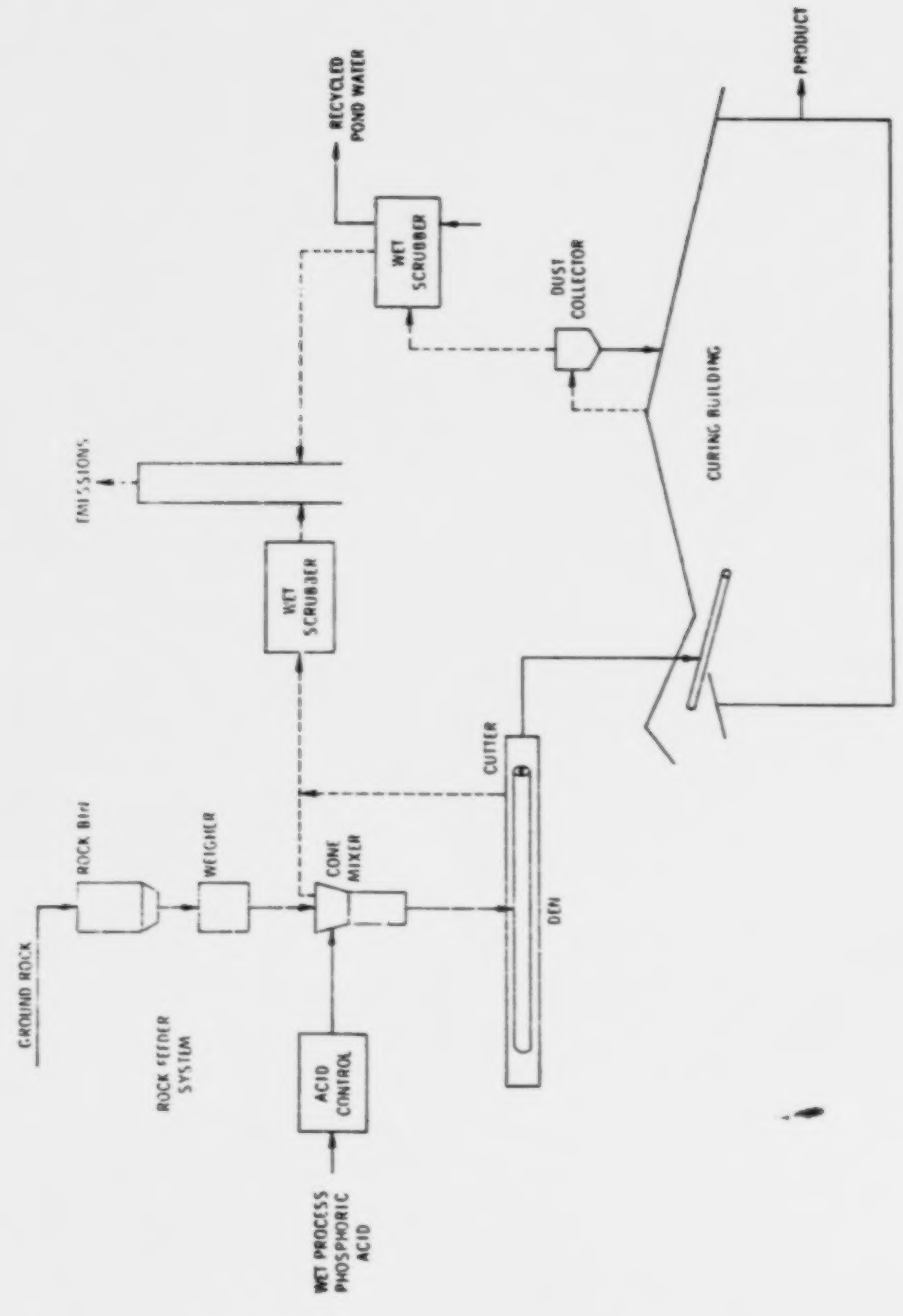

GROUND ROCK
ROCK FEEDER SYSTEM
ROCK BIN
WEIGHER
CONE MIXER
WET PROCESS PHOSPHORIC ACID
ACID CONTROL
DEN
CUTTER
WET SCRUBBER
EMISSIONS
WET SCRUBBER
RECYCLED POND WATER
DUST COLLECTOR
CURING BUILDING
PRODUCT

Figure 2-9. Process flow diagram of a typical ROP/TSP plant.[7]

volume exhausted from the cone mixer (pug mill) is not available because the source exhaust is combined with the curing belt or den.

The den or curing belt is used to allow the slurry from the mixer to react and evolve gas. The den is a major source of particulate and fluoride emissions. The belt is enclosed and ventilated to remove the particulates and fluorides. Typical gas rates are 20,000 to 40,000 acfm, but rates are highly variable depending on den design, tightness, and production rate. The tightness of the system can be maximized by a good O&M plan. No independent data are available concerning uncontrolled emission rates, but if compared with normal superphosphate (NSP) curing belts, an emission factor of 9 lb/ton is a good estimate. The options used for control of particulate emissions are cyclonic spray scrubbers, venturi/crossflow scrubbers, and venturi scrubbers. Only limited data are available on the controlled emission rate from the den (curing belt) because the source is combined with other sources. The limited data indicate rates of 0.04 to 0.31 lb/ton.

The dryer is employed in some plants to increase the chemical reaction by elevating the product temperature and removing moisture. The dryer is a significant source of particulate emissions; rate of flue gases from a dryer are between 25,000 and 30,000 acfm, but vary according to production requirements. Based on limited data, the control options are cyclonic spray scrubbers, venturi/crossflow scrubbers, and venturi scrubbers.

The controlled emission rates at plants in which dryers were controlled independently were 0.13 to 0.27 lb/ton. The cured ROP/TSP is transferred to storage and is aged before shipment.

The storage building is typically exhausted to control fluorides. The ventilation of the building exhausts the suspended particulates, which are generated by material movement within the building. The data collected do not indicate potential uncontrolled emissions, and only limited data are available on controls used. The control options are venturi scrubbers, cyclonic spray scrubbers, and venturi/packed bed scrubbers. The controlled emission rate, based on three sources of data, is 0.08 to 0.23 lb/ton, but the effectiveness of the building capture system is not known. Control can be maximized by a good O&M plan. The range of data may be the result of a variance in the capture efficiency of the collection system.

Based on all sources, the controlled emission rate is between 0.25 and 0.81 lb/ton (assuming all sources are controlled). To ensure that the control equipment emission rate truly reflects plant emissions requires complete and efficient capture of emissions from the curing den and dryer. The installation and operation of hood enclosures and ventilation systems in conjunction with an O&M plan have been demonstrated to reduce fugitive losses effectively within the plant. Good maintenance of the hoods and ductwork is necessary to maintain the level of control and minimize fugitive emissions. To ensure the continuous control of fugitive emissions requires an effective method of evaluating loss to the atmosphere. An opacity standard applied to fugitive loss from the building is an effective method of maintaining control of fugitive emissions. Plants using good capture practices can reasonably be expected to maintain fugitive losses from building vents at less than 5 percent opacity.

Table 2-7 lists emission sources and control options for ROP/TSP plants.

2.4.3 Control Costs

An estimate of the cost of the various control options discussed in the previous subsection is presented in Table 2-8. The cost and emission estimates are based on a theoretical plant producing ROP/TSP at 20 tons/h. The air volume and water flow rate are typical for plants in the area. The capital cost is based on data on file as part of permit applications with the State of Florida Department of Environmental Regulation in Tampa, Florida. The costs have been adjusted to January 1980 dollars by use of the C-E plant cost index.[3] Incomplete data are available concerning horsepower and liquor flow rates. Therefore, a pressure drop of 10 in. H_2O and liquor-to-gas ratio of 40 gal/1000 acfm have been used.

The recovered product has value as fertilizer material, and the water is typically returned to the process. In some cases the scrubbers are used as primary fluoride control, and the

TABLE 2-7. PARTICULATE EMISSION SOURCES AND CONTROL OPTIONS FOR ROP/TSP PLANTS

Source	Control options
Mixer, den (curing belt)	Venturi, venturi/spray cyclonic, spray cyclonic
Dryer	Spray cyclonic, venturi/crossflow
Storage	Venturi/cyclonic spray, venturi, cyclonic spray, impingement scrubber

TABLE 2-8. CONTROL COSTS OF A TYPICAL ROP/TSP PLANT[a]

Source of emissions	Control options	Control %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Mixer, pubmill, den	Cyclonic spray	97.6-99.6	9.0[c]	0.04-0.31	695.2	318,000	10	50,283	134,249	90,350	135
Dryer	Cyclonic spray	98.7-99.4	21.0[d]	0.13-0.27	1658	318,000	10	51,798	137,426	215,540	15

[a] Costs in January 1980 dollars. Basis: process weight of 20 tons/h.

[b] Based on a 10 percent cost of capital.

[c] Using emissions factor for NSP production.

[d] Using emission factor for GTSP dryer.

water is returned to the gypsum ponds. In the case of product recovery, the annual cost has been credited with the weight of the recovered products at $130/ton of recovered product.

Data are insufficient to determine adequately the uncontrolled emission rate from the dryer (optional). For purposes of calculation, the emission rate from a GTSP rotary dryer has been used as an upper limit. A primary cyclone is typically used ahead of the scrubber to recover product directly into the process.

The cost of control for a conventional den/pubmill is estimated to be $135/ton of material removed.

2.4.4 Recommended RACT

From a technological standpoint, the use of venturi scrubbers, cyclonic spray scrubbers, and crossflow scrubbers can achieve emission levels of 0.30 lb/ton of product from the pugmill and den. The dryer is an additional (optional) source at most plants. Where used, the dryer will not allow plant emissions to be reduced to the 0.30-lb/ton level. The emission level achievable by use of moderate control is 0.27 lb/ton; however, the application of venturi scrubbers/spray scrubbers will reduce emissions to 0.10 lb/ton.

It is recommended that allowable emissions from a conventional process be 0.25 lb/ton. When a dryer is used, that level should be increased to 0.35 lb/ton to accommodate the additional source loading.

The cost of particulate removal from the den is higher than the cost of particulate removal from the dryer because of the lower uncontrolled emission rate and the recovered product credit. A fugitive emission limit of 5 percent opacity from the den building is recommended to ensure a high capture efficiency. The use of well-designed hoods and enclosures is considered reasonable in achieving this level.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates because of the solubilization of the diammonium phosphate on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

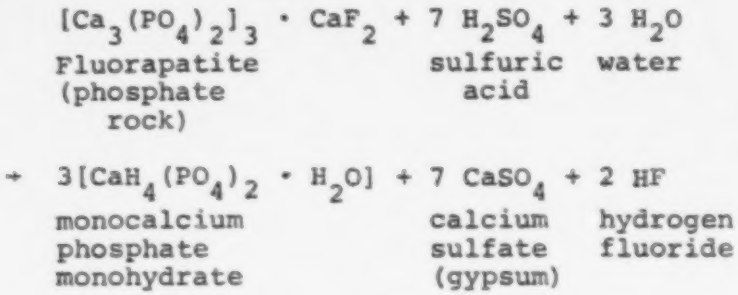
2.5 RUN-OF-THE-PILE NORMAL SUPER PHOSPHATE

This subsection discusses the processes used in the production of ROP/NSP and identifies the major particulate sources within each facility. The subsection also discusses the available control technology and cost of employing this technology. Based on this analysis. RACT recommendations are made.

2.5.1 Process Description

Reaction of sulfuric acid (65 percent to 75 percent) with ground phosphate rock (16 to 21 percent P_2O_5) is used to produce ROP/NSP. The chemical reaction converts the insoluble fluorapatite to the plant soluble monocalcium phosphate monohydrate.

The reaction produces calcium sulfate and hydrogen fluoride as secondary products by the following equation:



$$\underset{\substack{\text{Fluorapatite}\\\text{(phosphate}\\\text{rock)}}}{[Ca_3(PO_4)_2]_3 \cdot CaF_2} + \underset{\substack{\text{sulfuric}\\\text{acid}}}{7\,H_2SO_4} + \underset{\text{water}}{3\,H_2O}$$

$$\rightarrow \underset{\substack{\text{monocalcium}\\\text{phosphate}\\\text{monohydrate}}}{3[CaH_4(PO_4)_2 \cdot H_2O]} + \underset{\substack{\text{calcium}\\\text{sulfate}\\\text{(gypsum)}}}{7\,CaSO_4} + \underset{\substack{\text{hydrogen}\\\text{fluoride}}}{2\,HF}$$

The ground phosphate rock is reacted with the acid in a cone mixer in which the acid is introduced tangentially. The super phosphate is discharged from the mixer into a pugmill for complete mixing of the rock and acid. The mixer may be either continuous or batch depending on plant design.

The super phosphate slurry is discharged to a den for curing. Depending on the plant design, the den may be continuous or batch. In the continuous den, the product is allowed to react on a slow-moving belt as it is transferred to the curing building. The movement allows about 1 hour for the reaction of acid and rock to occur with the release of gases.

The batch den consists of a number of enclosed compartments in which the product is stored for 1.5 to 10 hours, during which time the material solidifies. The solid NSP product is removed from the den and cut or broken before transfer to the curing area.

The product is a porous honeycomb in appearance when solidified and must be cut or broken before being placed in the curing area. The product is stored in the curing building for 2 to 6 weeks to permit the reaction to go to completion. Following curing, the product is ground and bagged for shipment. The cone mixer, pugmill, and den are sources of particulate emissions and are controlled by scrubbers.

Review of the processes operated in the central Florida phosphate producing area indicated two facilities that have produced ROP/NSP in recent years. The production rate of the lines were 13 and 15 tons/h. Figure 2-10 is a process flow diagram of a typical ROP/NSP plant.

2.5.2 Emission Sources and Control Options

Four major points of particulate emissions in a conventional NSP plant are listed below:

(1) Mixer

(2) Pugmill

(3) Curing belt/den (continuous/batch)

(4) Curing building

The mixer, pugmill, and den are sources of particulate emissions because of the reaction of sulfuric acid on the phosphate rock. The reaction generates heat and releases steam and hydrogen fluoride. The sources are hooded, and the emissions are controlled by a scrubber. The ventilation rate varies with plant size. Data indicate typical gas rates of 15,000 to 25,000 acfm.

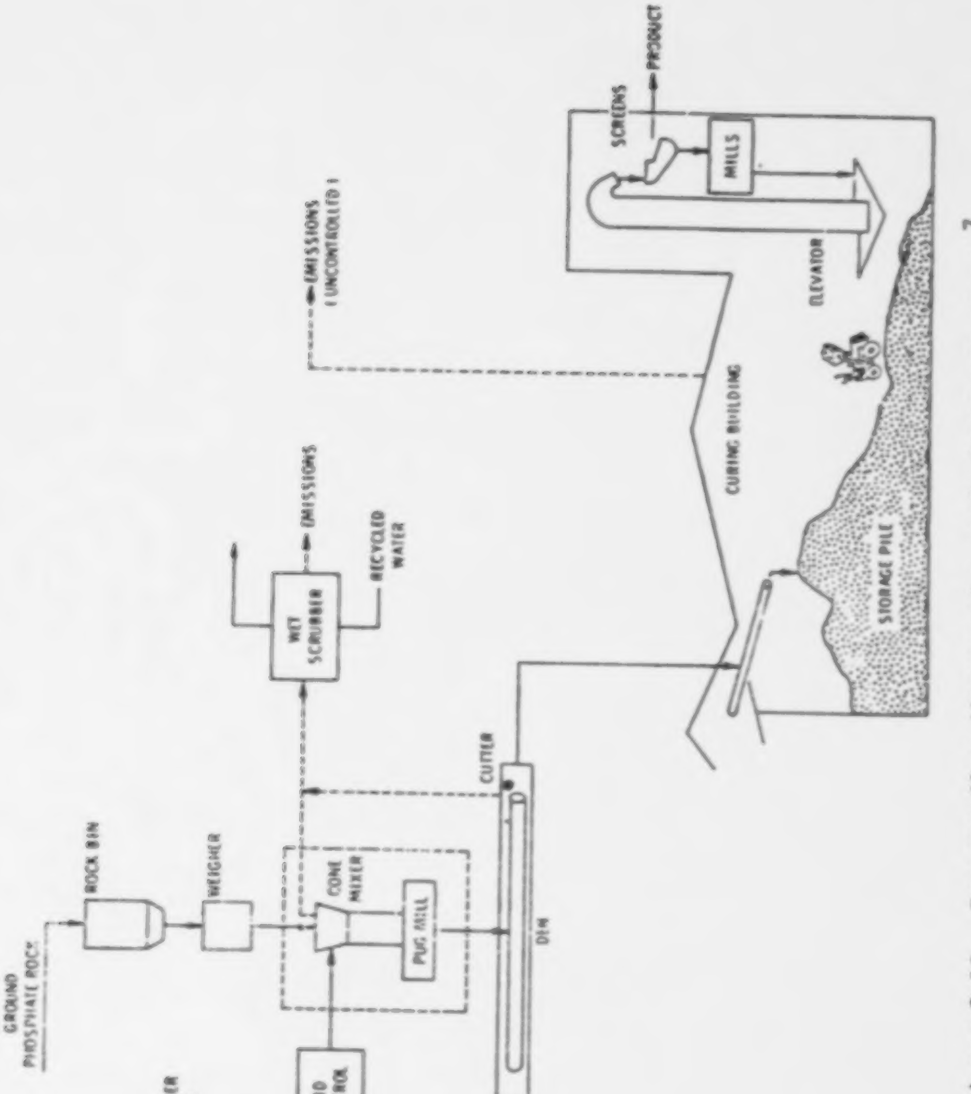

GROUND PHOSPHATE ROCK
ROCK BIN
WEIGHER
ROCK FEEDER SYSTEM
SULFURIC ACID
ACID CONTROL
CONE MIXER
PUG MILL
DEN
CUTTER
WET SCRUBBER
EMISSIONS
RECYCLED WATER
EMISSIONS (UNCONTROLLED)
CURING BUILDING
STORAGE PILE
ELEVATOR
MILLS
SCREENS
PRODUCT

Figure 2-10. Process flow diagram of a typical ROP/NSP plant.[7]

Uncontrolled emission rates from these sources are reported to be 9 lb/ton.[6] The accuracy of the value as applied to general sources is questionable because the range of gas rates and production rates.

Typical control options consist of venturi scrubbers, wet impingement scrubbers, and cyclonic spray scrubbers. Based on State of Florida files and EPA data, 7 controlled emission rates range between 0.02 and 0.20 lb/ton ROP/NSP.

2.5.3 Control Costs

An estimate of the cost of the various control options discussed in the previous subsubsection is presented in Table 2-9. The cost and emission estimates are based on a theoretical plant producing ROP/NSP at 15 ton/h. The capital cost is based on data on file as part of permit applications with the State of Florida Department of Environmental Regulation in Tampa, Florida. The cost has been adjusted to January 1980 dollars by use of C-E plant cost index.[3] Incomplete data are available for fan horsepower and liquor flow rates. A pressure drop of 10 in. H_2O and liquor-to-gas ratio of 40 gal/1000 acfm have been estimated.

The recovered product has value as fertilizer material, and the water is typically returned to the process. In some cases the scrubbers are used for primary fluoride control, and the water is returned to the gypsum ponds. In the case of product recovery, the annual cost has been credited with the controlled weight at $130/ton of recovered product.

TABLE 2-9. CONTROL COSTS OF A TYPICAL ROP/NSP PLANT[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Mixer, den	Cyclonic spray	97.4	9.0	0.15-0.23	526.2	159,000	10	25,874	116,712	68,406	140
Mixer, den	Impingement	99.8	9.0	0.01	539.4	c	c	c	c	c	c

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Insufficient data.

2.5.4 Recommended RACT

The use of cyclonic spray scrubbers and wet impingement scrubbers can achieve an emission limit of 0.25 lb/ton.

The cost of product recovery is approximately equal to the value of the recovered product. At a cost of $140/ton recovered, the cost represents only 0.4 percent of the product value per year.

A fugitive emission limit of 5 percent opacity from the den building is recommended to ensure a high capture efficiency. The use of well-designed hoods and enclosures along with a good O&M plan are reasonable in achieving this level.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of the solubilization of the diammonium phosphate on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

2.6 ANIMAL FEED INGREDIENTS

This subsection discusses the processes used in the production of AFI and identifies the major particulate emission sources within each process. The subsection also discusses the variable control technology and cost of using the technology. Based on this analysis, RACT recommendations are made.

The term "animal feed ingredients" refers to a number of calcium phosphate compounds produced by use of defluorinated phosphoric acid or wet process phosphoric acid.

Two companies manufacture these products in the Tampa area. Because each company considers the process technology to be confidential, limited process data are available; however, based on general discussions and information available through the Florida Department of Environmental Resources records, the processes have been classified into three major categories. The first category involves the production of granular monoammonium and diammonium phosphate with defluorinated phosphoric acid. The second category involves the production of calcium phosphates with defluorinated phosphoric acid and limestone. The third category involves the production of calcium phosphates with wet process phosphoric acid from phosphate rock with product defluorination after reaction. Although each process is described individually, the first two processes can be accomplished on the same process line.

2.6.1 AFI ammonium phosphate

Process Description--

Monoammonium and diammonium phosphate--The production of monoammonium and diammonium phosphate AFI is similar to the production of granular ammonium phosphates. Figure 2-11 is a process flow diagram of a typical TVA ammonium phosphate AFI plant. The ammonium phosphate slurry is produced by the reaction of defluorinated phosphoric acid with ammonia in an

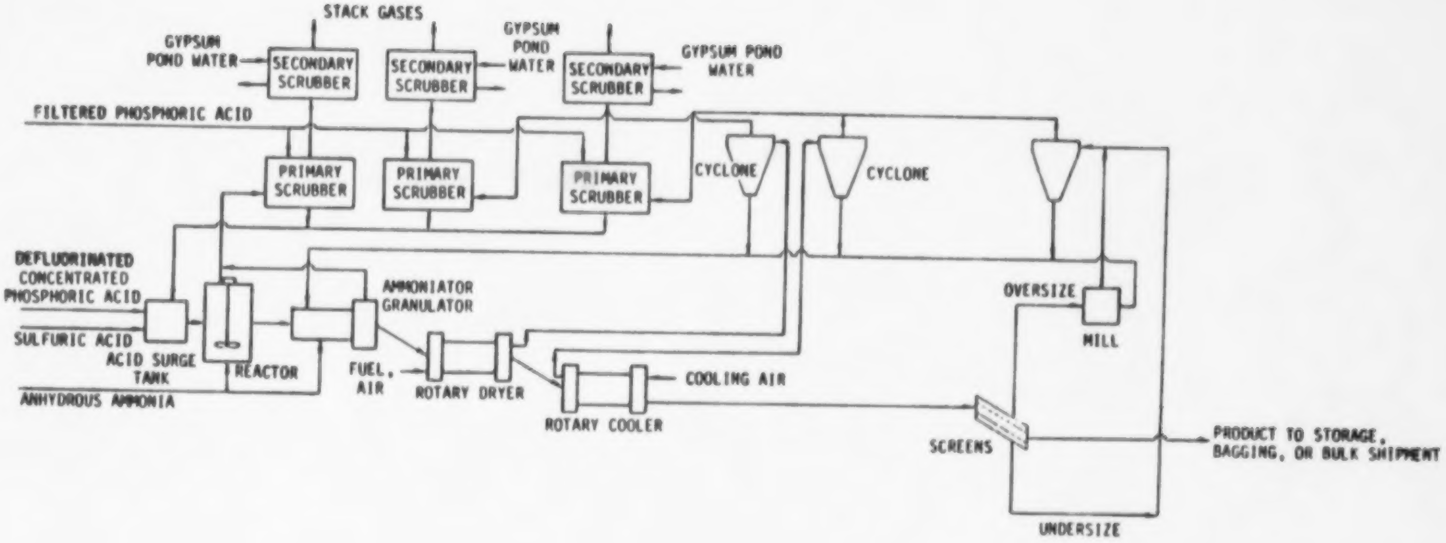

STACK GASES
GYPSUM POND WATER
SECONDARY SCRUBBER
SECONDARY SCRUBBER
GYPSUM POND WATER
SECONDARY SCRUBBER
GYPSUM POND WATER
FILTERED PHOSPHORIC ACID
PRIMARY SCRUBBER
PRIMARY SCRUBBER
PRIMARY SCRUBBER
CYCLONE
CYCLONE
DEFLUORINATED CONCENTRATED PHOSPHORIC ACID
SULFURIC ACID
ACID SURGE TANK
REACTOR
ANHYDROUS AMMONIA
AMMONIATOR GRANULATOR
FUEL, AIR
ROTARY DRYER
ROTARY COOLER
COOLING AIR
OVERSIZE
MILL
SCREENS
UNDERSIZE
PRODUCT TO STORAGE, BAGGING, OR BULK SHIPMENT

Figure 2-11. Process flow diagram of a typical TVA AFI, ammonium phosphate plant.[7]

aggitated reactor. The slurry is pumped into a rotary granulator in which granules are formed by coating and agglomerating on recycled product fines. The chemical composition of the product is controlled by the temperature and rate of ammonia and acid injection into the granulator. The product is discharged to a rotary dryer, which reduces the moisture content to less than 2 percent.

The product is elevated by bucket elevators to a series of vibrating screens. The oversize material is ground with cage mills, and the fines are returned to the granulator. The screened product is cooled in a rotary cooler and rescreened for shipment.

The granulator, reactor, dryer, cooler, cage mills, screens, and conveying equipment are exhausted to capture particulate emissions and are controlled by simple cyclones followed by scrubbers.

Mono calcium and dicalcium phosphate--Defluorinated phosphoric acid can be used to produce AFI consisting of dicalcium and monocalcium phosphates in granular form. Figure 2-12 is a process flow diagram of a typical calcium phosphate AFI plant. The process involves the reaction of limestone and defluorinated phosphoric acid in a pugmill to form a slurry. The slurry is transferred to the rotary dryer and processed in a similar manner to the ammonium phosphate products with fines recycled and returned to the pugmill.

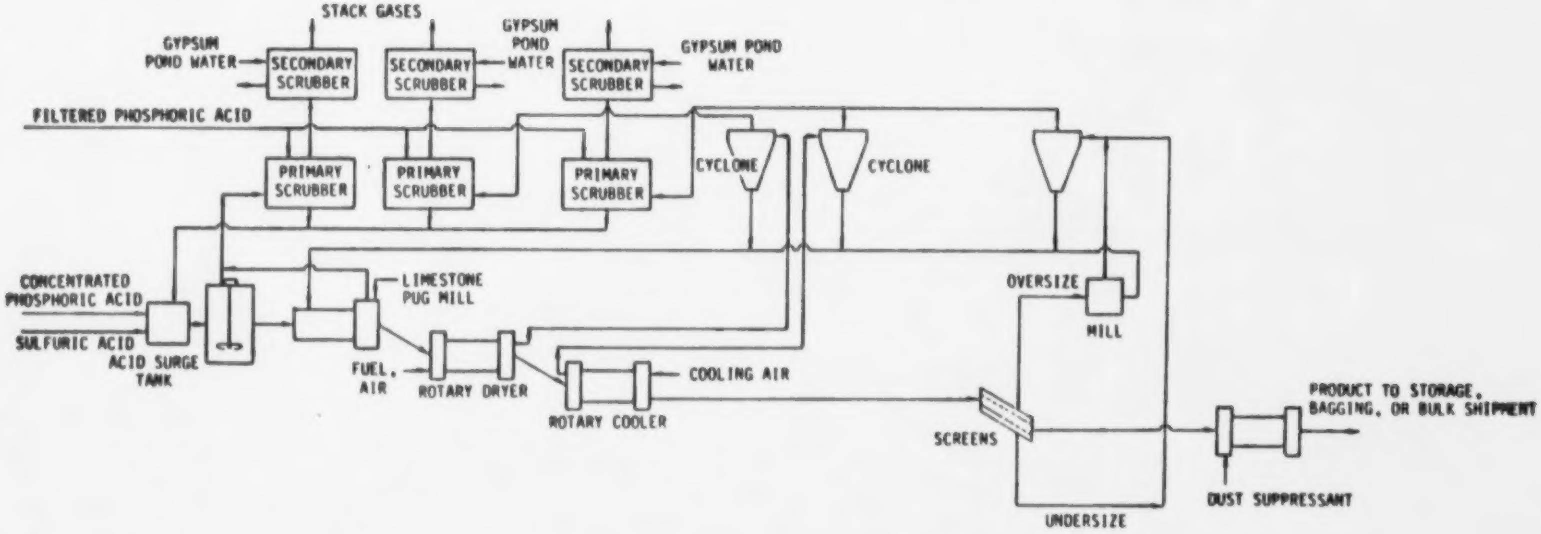

STACK GASES
GYPSUM POND WATER
SECONDARY SCRUBBER
SECONDARY SCRUBBER
GYPSUM POND WATER
SECONDARY SCRUBBER
GYPSUM POND WATER
FILTERED PHOSPHORIC ACID
PRIMARY SCRUBBER
PRIMARY SCRUBBER
PRIMARY SCRUBBER
CYCLONE
CYCLONE
CONCENTRATED PHOSPHORIC ACID
SULFURIC ACID
ACID SURGE TANK
LIMESTONE
PUG MILL
FUEL, AIR
ROTARY DRYER
ROTARY COOLER
COOLING AIR
OVERSIZE
MILL
SCREENS
UNDERSIZE
DUST SUPPRESSANT
PRODUCT TO STORAGE, BAGGING, OR BULK SHIPMENT

Figure 2-12. Process flow diagram of a typical AFI calcium phosphate plant.[7]

The pugmill, dryer, screens, cage mills, cooler, and transport equipment are exhausted. and particulate emissions are controlled by simple cyclones followed by scrubbers.

Emission Sources and Control Options--

One plant produces monoammonium and diammonium phosphate AFI from defluorinated phosphoric acid. The major emission sources are listed below:

(1) Reactor
(2) Granulator (pugmill)
(3) Dryer
(4) Screens and cage mills
(5) Cooler
(6) Bucket elevator, conveyors, etc.

The general process flow of the product is similar in design to that at a TVA diammonium phosphate plant except that the finished granules are larger.

The reactor is a source of fluorides and ammonia and is typically vented with the ammonia granulator gases. The exhaust rate from the reactor is about 3000 acfm at 220°F. The exhaust from the granulator (or pugmill) is about 30,000 acfm at 180°F. The particulate loading is 27 lb/ton, and the ammonia loading is 30 lb/ton, based on conventional DAP plant estimates. A typical control method used for this emission source is a venturi scrubber followed by a crossflow scrubber. The system operates at a pressure drop of 14 in. H_2O and liquor-to-gas ratio of 20 gal/1000 acfm; phosphoric acid is used as the scrubbing liquor.

The rotary dryer is a major source of particulate emissions. The dryer is fired with fuel oil at a heat input of 960,000 Btu/ton of product. The typical dryer exhaust rate is 82,000 acfm at 250°F. The uncontrolled particulate emission rate, after the reclaim cyclone, is estimated at 32 lb/ton (based on conventional DAP plant estimates). Emissions are controlled by a venturi scrubber followed by a crossflow scrubber. The scrubber operates at a pressure drop of 14 in. H_2O and liquor-to-gas ratio of 10 gal/1000 acfm.

The cooler, screens, cage mills, and product handling equipment are vented to a product recovery cyclone and then to a venturi scrubber, followed by a crossflow scrubber. The typical gas rate is 71,500 acfm at 160°F (the cooler rate is 44,500 acfm). The venturi has a pressure drop of 14 in. H_2O and liquor-to-gas ratio of 11 gal/1000 acfm. The emission rate from the combined scrubber exhaust has been reported as 0.28 lb/ton.

Control Costs--

An estimate of the cost of the various control options discussed in the previous subsection is presented in Table 2-10. The cost and emission estimates are based on a theoretical plant producing granular AFI at 120 ton/h. The air volume and water flow rate are considered typical of plants in the area. The capital cost is based on data on file as part of permit applications with the State of Florida Department of

TABLE 2-10. CONTROL COSTS OF A TYPICAL AFI AMMONIUM PHOSPHATE PLANT[a]

Source of emissions	Control options	Control %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Reactor, granulator, pug mill, dryer, cooler, mills, screens, transfer	Venturi/ cross-flow	99.6	85	0.28	30,500[c]	2,500,000	10	406,875	626,737	5,490,000[d]	(146)

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Average production of 90 ton/h at 8000 h/yr.

[d] Recovered product returned to process at a value of $180/ton.

Environmental Regulation in Tampa, Florida. The cost has been adjusted to January 1980 dollars by use of the C-E plant cost index.[3]

Figure 2-13 represents the control system arrangement used at one facility surveyed. Information on specifics at the second facility were not available. The annualized cost is computed based on the total system gas volume, water rate and static pressure drop.

Because of the proprietary nature of the AFI processes and the lack of field data, uncontrolled emission factors are unavailable; however, the basic process used is similar to a diammonium phosphate plant. For the purposes of emission calculations, the emission factor is assumed to be 85 lb/ton and that the recovered product has a value of $180 ton.

As with other ammonium phosphate and calcium phosphate processes, the primary scrubbers are used as process recovery devices, with the acid slurry being returned to the reactor or granulator. A net annualized credit is estimated to be $146/ton removed.

Recommended RACT--

Limited data on this process indicate that the use of venturi scrubber and crossflow scrubbers can achieve an emission limit of 0.30 lb/ton of product. The cost of control is not a critical factor since the application of credit for product recovered results in a recovered value greater than the annualized cost.

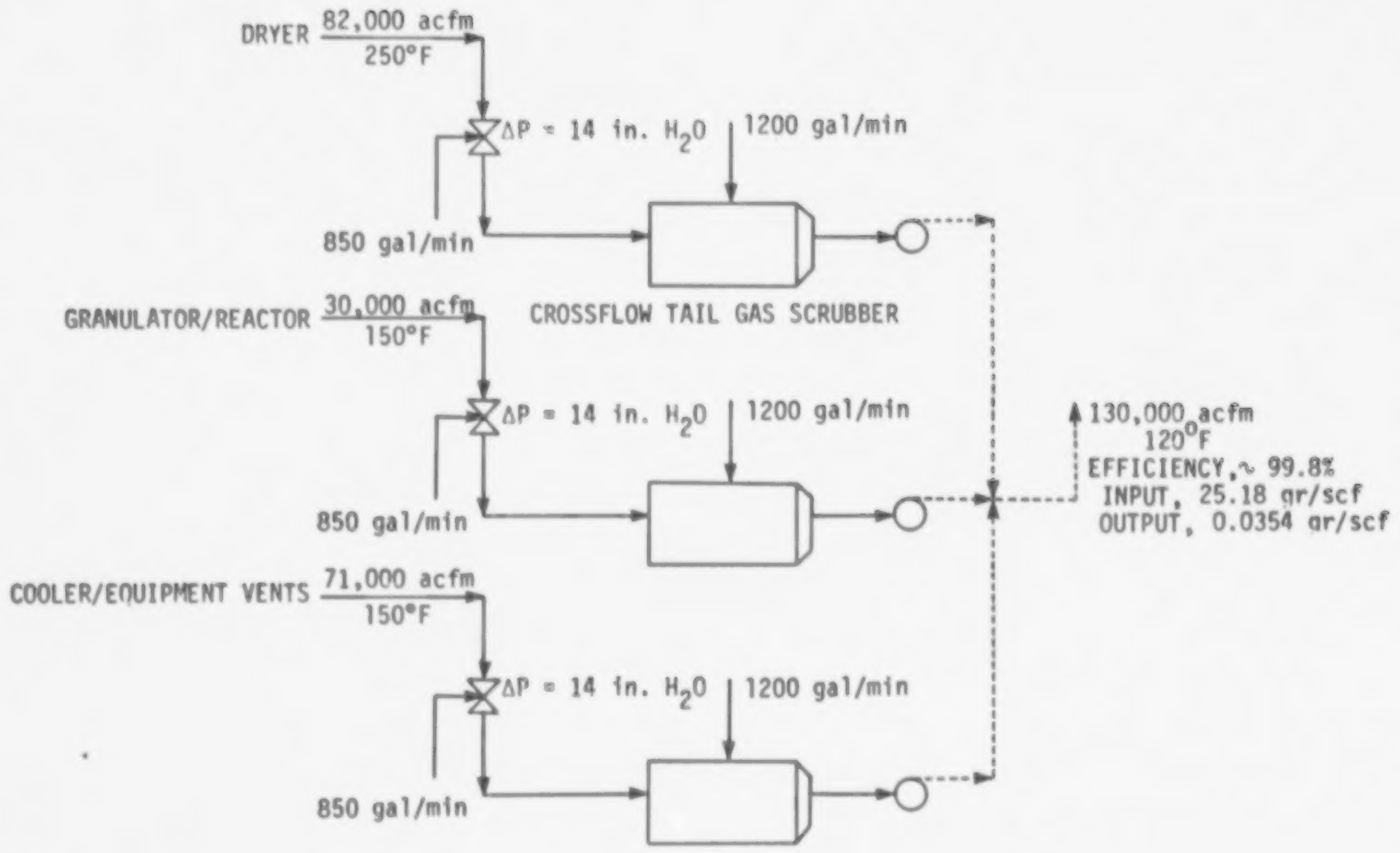

DRYER
82,000 acfm
250°F
ΔP = 14 in. H_2O
1200 gal/min
850 gal/min
CROSSFLOW TAIL GAS SCRUBBER
GRANULATOR/REACTOR
30,000 acfm
150°F
ΔP = 14 in. H_2O
1200 gal/min
850 gal/min
COOLER/EQUIPMENT VENTS
71,000 acfm
150°F
ΔP = 14 in. H_2O
1200 gal/min
850 gal/min
130,000 acfm
120°F
EFFICIENCY, ~ 99.8%
INPUT, 25.18 gr/scf
OUTPUT, 0.0354 gr/scf

Figure 2-13. Process flow diagram of a typical AFI (monoammonium/diammonium phosphate) granulation plant using venturi scrubbing and crossflow tail gas scrubbing.

To assure that the emissions measured by the stack test represent the controlled emission level, a fugitive emission limit applied to the plant process building in conjunction with an O&M plan is recommended. The fugitive emissions are judged based on the opacity of material escaping the building. This level is recommended to be 5 percent opacity; based on good maintenance and good hood capture, the level should be easily achieved.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of the solubilization of the diammonium phosphate on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

2.6.2 Calcium Phosphate from Phosphate Rock

Process Description--

The production of calcium phosphate AFI from phosphate rock involves the defluorination of the rock after formation of the complex.

The general process consists of the reaction of phosphate rock and wet process phosphoric acid (containing fluorides) and the aging of the product. The product is mixed with several ingredients (salts, composition not provided) and calcined at temperatures in excess of 2000°F in rotary kilns on fluid bed reactors to remove the fluorides. The calcination changes the chemical structure of the calcium phosphate making it available for animal assimilation. The calcined product is cooled in a rotary cooler and screened and crushed for shipment.

Variations of the process can involve the further reaction of the calcined product with defluorinated phosphoric acid and limestone to increase the grade of the product.

Particulate emissions occur from the calcining kilns and reactors, product cooling, and product transfer and storage. Particulate emissions from these sources are typically controlled by simple cyclones and scrubbers. Figure 2-14 is a process flow diagram for the production of AFI using the wet process phosphoric acid process with fluorine removal by calcining.

Emission Sources and Control Options--

There are two plants which produce AFI from phosphate rock. The major source of particulate emissions from these processes is the defluorination kilns or reactors (fluid bed). The general process involves the calcining of the prepared animal feed ingredient in a rotary kiln. Data are limited on the specific emission or process conditions of these sources since both companies consider the process technology confidential. Limited data, however, indicate that the typical kiln has an exhaust volume between 40,000-45,000 acfm at 1200°F. The uncontrolled emission rate is estimated at 5.5 gr/dscf (60 lb/ton). Typical firing rates are 484 x 10^6 Btu/h using residual oil. The emissions are typically controlled by packed

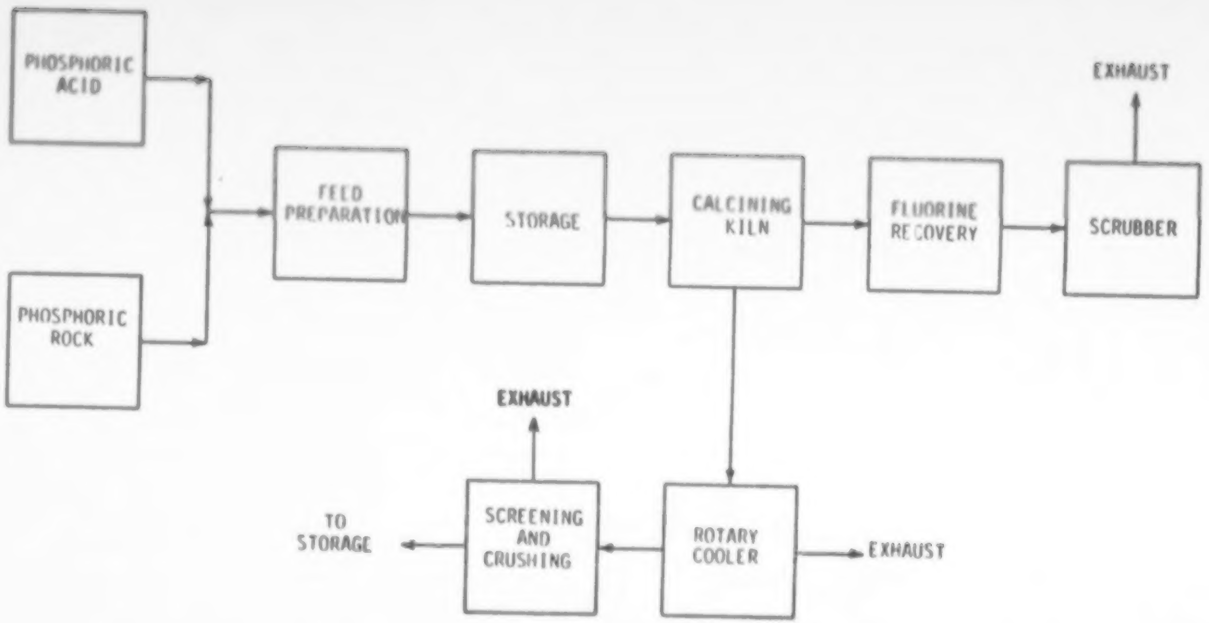

PHOSPHORIC ACID
PHOSPHORIC ROCK
FEED PREPARATION
STORAGE
CALCINING KILN
FLUORINE RECOVERY
SCRUBBER
EXHAUST
EXHAUST
SCREENING AND CRUSHING
ROTARY COOLER
EXHAUST
TO STORAGE

Figure 2-14. Process flow diagram of AFI production by the wet phosphoric acid process with fluorine removal by calcining.

bed or venturi scrubbers. Few data are available concerning the operating conditions of these scrubbers. Based on limited data, the crossflow scrubber has been estimated to be operated at a liquor-to-gas ratio of 55 gal/1000 acfm (2200 gpm) with the major portion of the water being used to quench the kiln gases before entering the scrubber.

Reported emission rates for the systems for the venturi are 0.63 lb/ton, while those for the crossflow scrubber are 0.23 lb/ton.

Control Costs--

An estimate of the cost of the various control options discussed in the previous subsection is presented in Table 2-11. The cost and emission estimates are based on a theoretical plant producing 14 ton/h of calcined AFI. The air volume and water flow rate are considered typical of plants in the area. The capital cost is based on data on file as part of permit applications with the State of Florida Department of Environmental Regulation in Tampa, Florida. The cost has been adjusted to January 1980 dollars by use of the C-E plant cost index.[3]

The uncontrolled particulate emission rate is estimated by the industry to be 5.5 gr/dscf (60 lb/ton). If the calcine particulate is returned to the process, the estimated credit for removal is $40/ton removed; however, if the material is not recoverable, the cost of removal is $139/ton removed. It is

TABLE 2-11. CONTROL COSTS OF A TYPICAL AFI CALCIUM PHOSPHATE PLANT[a]

Source of emissions	Control options	Control %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Calciner	Cross-flow[c]	99.9	60	0.23	2390	833,300	10	135,554	198,089	430,200	139[d] or (40)[e]
Calciner	Venturi/ cyclonic spray	99.9	60	0.63	2375	f	f	f	f	f	f

[a] Costs in January 1980 dollars. Basis: process weight of 10 tons/h.

[b] Based on a 10 percent cost of capital.

[c] Gas flow rate of 12,700 dscfm and 200-hp fan at water rate of 2200 gal/min.

[d] If collected material cannot be returned to process.

[e] Collected material returned to process at $180/ton.

[f] Insufficient data.

probable that the primary cyclone catch may be returned and that the slurry may not be returned. In such case, an overall credit of $11/ton removed results.

Recommended RACT--

Limited data on this process indicate that the use of venturi scrubbers and crossflow scrubbers can achieve an emission limit of 0.25 lb/ton of product.

The cost of control is assumed not to be a factor since the recovered product is returned to the process and the credit exceeds the annualized control cost.

To assure that the emissions measured by the stack test represent the controlled emission level, a fugitive emission limit is recommended for the plant process building. The fugitive emissions are judged based on the opacity of material escaping the building. This level is recommended to be 5 percent opacity; based on good maintenance and good hood capture, the level should be easily achieved.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates because of the solubilization of the diammonium phosphate on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

2.7 PHOSPHATE ROCK DRYERS

This subsection discusses the processes used in the drying of phosphate rock and identifies the major particulate sources within each facility. The subsection also discusses the available control technology and cost of a typical plant using this technology. From this analysis RACT recommendations are made.

2.7.1 Process Description

The phosphate rock industry consists of rock processing operations located near ore reserves and mining operations. Nearly three-quarters of the national production of phosphate rock occurs in Florida; this production is used primarily for phosphate fertilizer. About 20 percent is converted to animal feed ingredients, and 30 percent is exported for further processing.

The constituent of the rock that is of economic interest is tricalcium phosphate [$Ca_3\ (PO_4)_2$], commonly known in the industry as bone phosphate of lime (BPL). Phosphate rock and products are typically graded on BPL content (e.g., 68 BPL rock contains 68 percent by weight of BPL or tricalcium phosphate). Final products usually contain 68 to 74 percent tricalcium phosphate.

Fluoride-bearing material is another constituent in phosphate rock accounting for 4 to 5 percent by weight. The basic structure of the fluoride ingredient is represented as fluorapatite ($3\ Ca_3\ (PO_4)_2 \cdot Ca_2F$). Most phosphate ores contain a substituted form of this structure, with fluoride and carbonate replacing some of the phosphate. Commercial rock contains 30 to 38 percent P_2O_5, with trace amounts of iron, aluminum, magnesium, silica, sodium, potassium, carbon dioxide and sulfates.

Florida phosphate rock deposits consist of a consolidated mass of phosphate pebbles and clays, known as matrix. The high clay content in Florida rock distinguishes it from other regional phosphate deposits. Figure 2-15 is a general flow diagram for processing of Florida phosphate rock. After the rock is mined, two intermediate-product types, pebble and concentrate, are produced, depending on the extent of benefication. Pebble is produced after the mined ore is washed; concentrate is the product after the ore is crushed and washed. Final product usage determines whether the ore is processed as pebble or concentrate. The distinction between pebble and concentrate is made in this text because of the higher emission rates associated with the handling and drying of pebble.

Another characteristic of Florida phosphate deposits is low organic content. Because most Florida rock is relatively free of organic material, calcining is not needed after benefication. Rock reserves containing organic materials require heating up to 1600°F to volatilize organics prior to further processing for fertilizer manufacturer.

Phosphate rock drying is accomplished in direct-fired dryers by heating the ore to 250°F for free water evaporation. Figure 2-16 is a process flow diagram of typical rock drying plant. Wet phosphate ore is conveyed and charged to the dryer

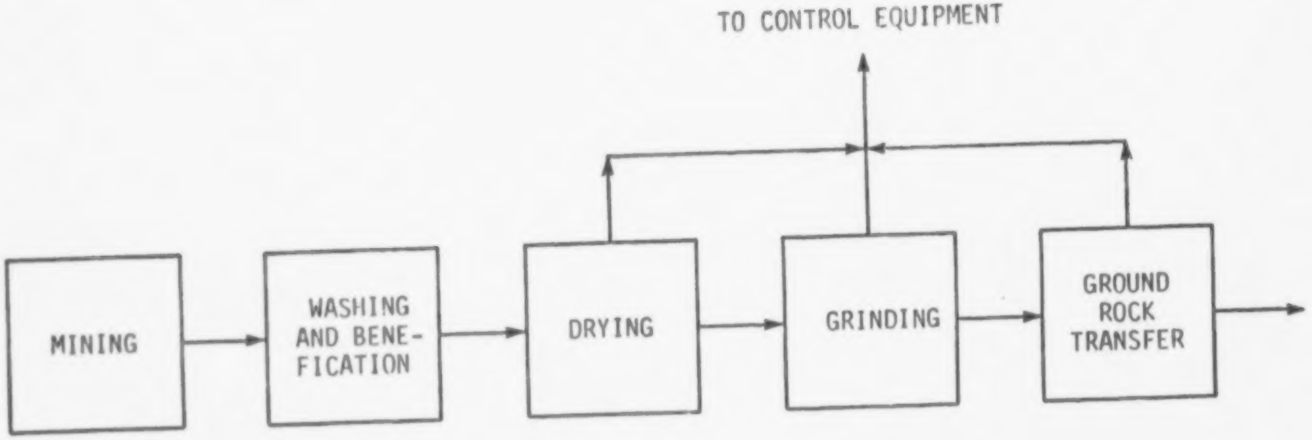

TO CONTROL EQUIPMENT
MINING
WASHING AND BENE-FICATION
DRYING
GRINDING
GROUND ROCK TRANSFER

Figure 2-15. Process flow diagram of Florida phosphate rock production.

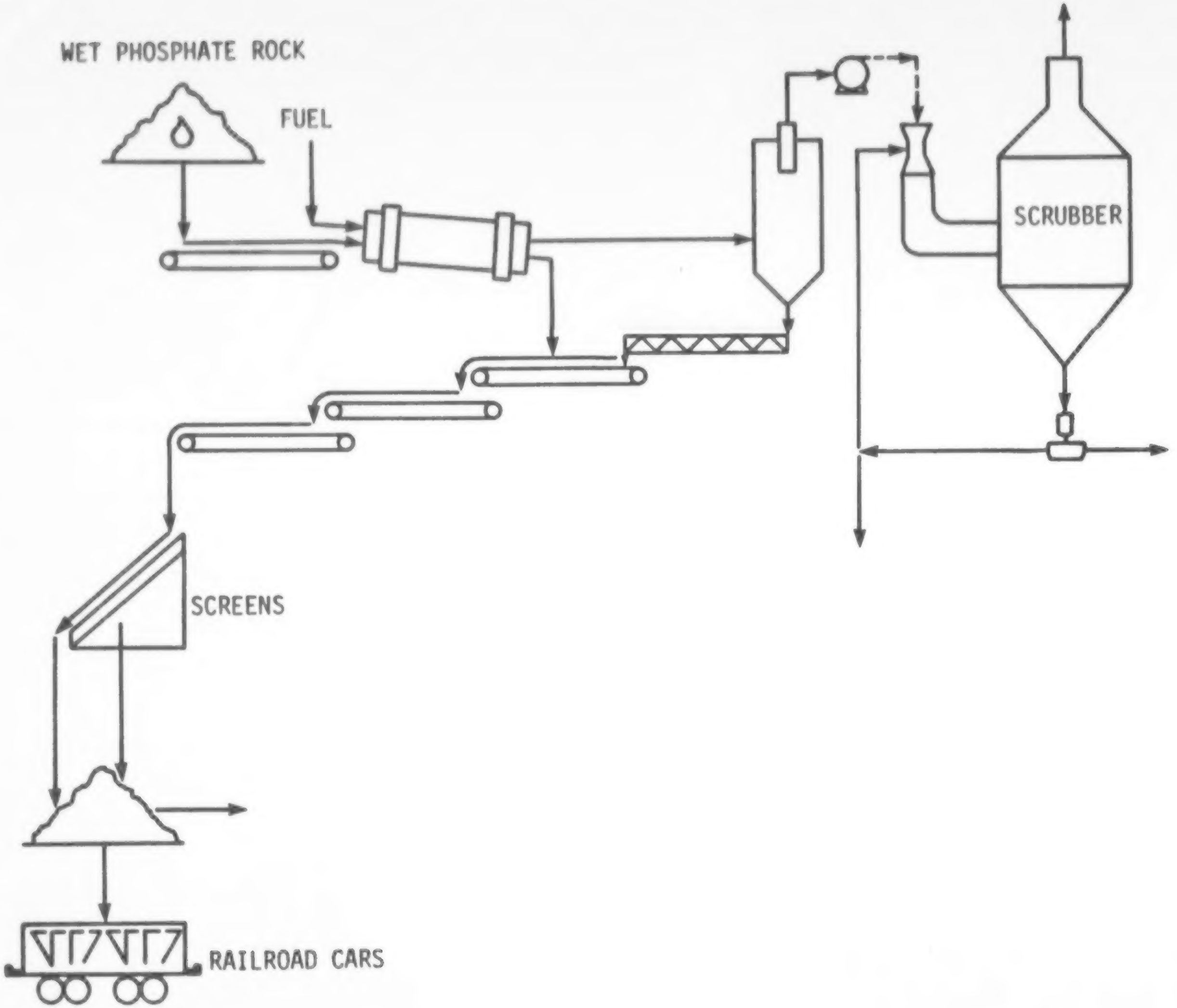

WET PHOSPHATE ROCK
FUEL
SCRUBBER
SCREENS
RAILROAD CARS

Figure 2-16. Process flow diagram of a typical phosphate rock drying plant.

through a feed bin or feed chute. Petroleum-based fuels (natural gas, No. 2 and No. 6 fuel oil) are used for heating and drying the ore. The ore is discharged when the moisture content of the phosphate material is reduced from 14 percent down to 1 to 3 percent, depending on product use. There are two dryer designs utilized for this process: rotary dryers and fluidized-bed dryers. Figures 2-17 and 2-18 show typical schematics of these two types. After drying, the phosphate material is belt-conveyed to a screen house, where it is classified by size and transferred to storage or to a grinding process. The exhaust gas from the dryer contains entrained ore particles, combustion products, and moisture from ore drying. The dryer gas effluent is first controlled by a cyclone, where product recovery occurs, and then by a final emission control device.

Inventory of Florida state files indicated the capacities of dryers ranged from 5 to 500 tons/h with equal usage of both dryer designs. Based on state file records, an average dryer capacity is approximately 200 ton/h.

2.7.2 Emission Sources and Control Options

There are two major points of particulate emissions in a conventional phosphate rock dryer process plant:

1) Dryer
2) Dried materials handling and storage, including screen house

The characteristics of the exhaust gas from conventional dryers are indicated in Table 2-12. Emissions from rock dryers are dependent on several factors, including rock type (pebble or

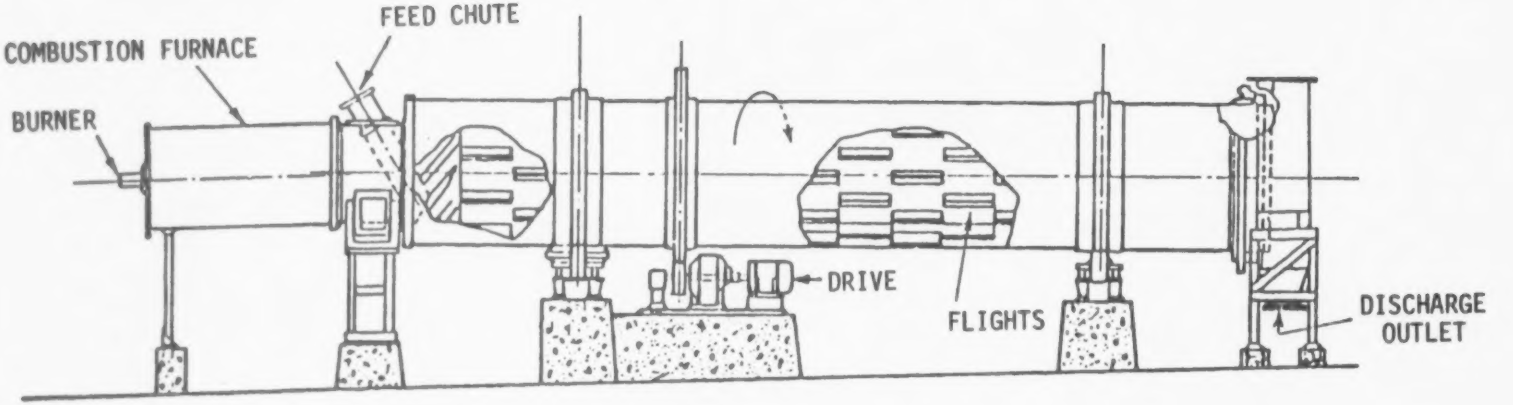

FEED CHUTE
COMBUSTION FURNACE
BURNER
DRIVE
FLIGHTS
DISCHARGE OUTLET

Figure 2-17. Direct-fired, cocurrent, rotary dryer.

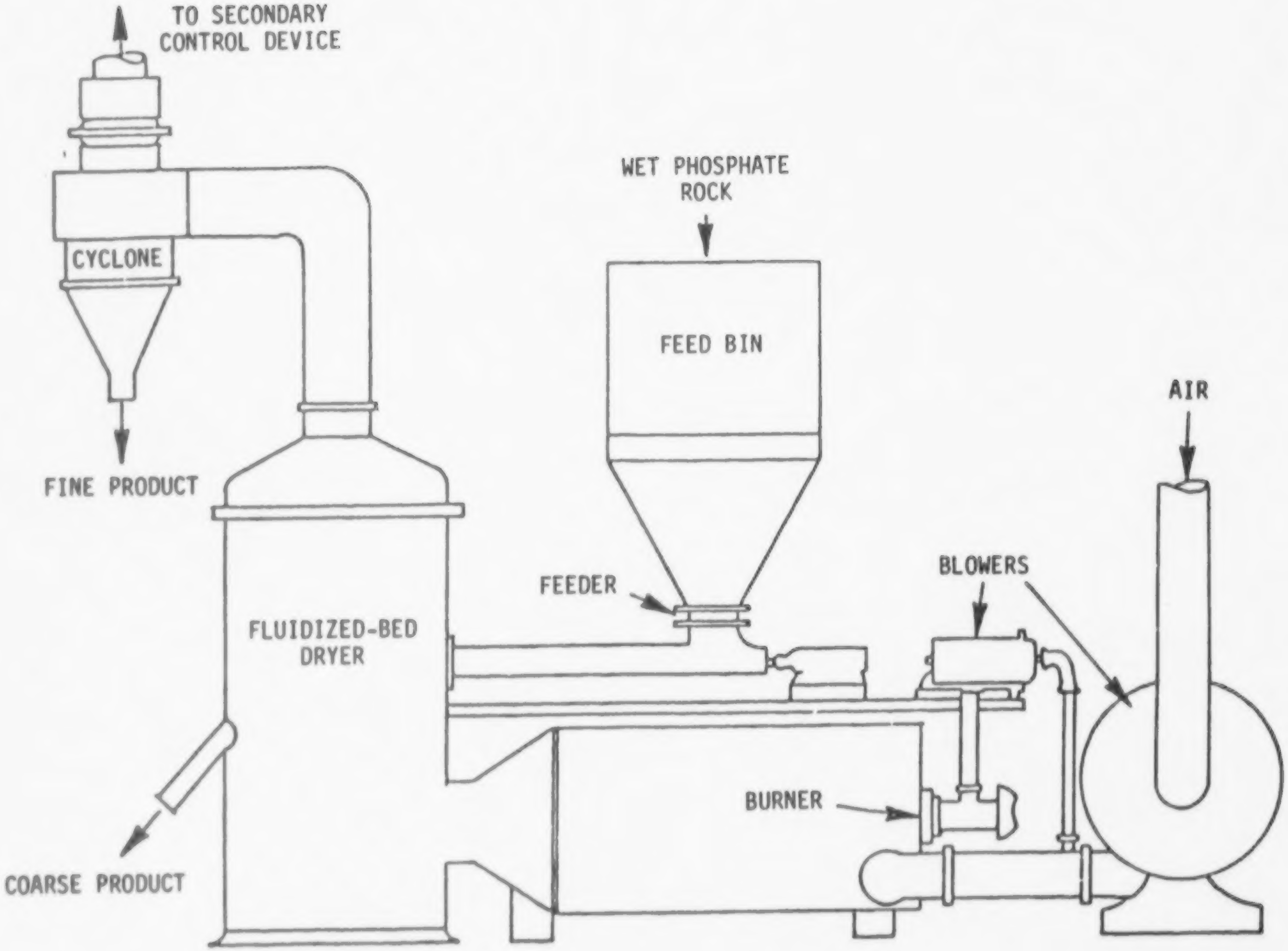

TO SECONDARY
CONTROL DEVICE
CYCLONE
FINE PRODUCT
WET PHOSPHATE
ROCK
FEED BIN
AIR
FEEDER
BLOWERS
FLUIDIZED-BED
DRYER
BURNER
COARSE PRODUCT

Figure 2-18. Fluidized-bed dryer.

TABLE 2-12. CHARACTERISTICS OF EXHAUST GAS FROM ROTARY AND FLUIDIZED-BED DRYERS

Exhaust flow rate	0.13-0.23 m^3/s per Mg product/h (250-450 scfm per ton product/h)
Temperature	394-422 K (250°-300°F)
Moisture	8-30%
Uncontrolled mass emissions	2-9 g/kg product (4-18 lb/ton product)
Grain loading	7-11 g/dry m^3 (3-5 gr/dscf)
Particle size distribution	98% <10 μm 92.9% < 5 μm 73.8% < 2 μm 39.9% < 1 μm 7.2% < 0.5 μm

concentrate), fuel type, air flow rate, product moisture content, and speed of rotation for the case of rotary dryers. The gas rates reported for individual driers range from 4000 to 160,000 scfm, corresponding to process rates ranging from 5 to 480 ton/h. For the considered representative case processing 200 ton/h of dried rock, it is estimated that 80,000 scfm of gas is exhausted from a reasonably operated and controlled source.

For all rock drying facilities processing more than 80 ton/h of product, scrubber systems were used for particulate control. A summary of control options used in the Central Florida area is presented in Table 2-13. Venturi scrubbers were most commonly used, followed by cyclonic scrubbers and then impingement-type scrubbers. Following most scrubber units were cyclonic-type mist eliminators to collect and remove entrained droplets. Typical scrubber system pressure drops ranged from 10 to 25 in. H_2O, and liquid-to-gas ratios ranged from 5 to 15 gal/1000 acfm.

A review of stack test results from several dryer facilities indicated emission rates of 0.01 to 0.11 lb/ton of dried product. Grouping of emission rates indicated that each control system type achieved emission rates less than 0.10 lb/ton on a consistent basis. Achievement of emission rates in the 0.03-0.04 lb/ton range was not uncommon.

Fugitive emissions from dried rock materials handling need to be controlled. An O&M plan is also necessary. Due to the dampness of feed material to the dryer, there are no fugitive emissions associated with dryer charging. Rock discharged from

TABLE 2-13. PARTICULATE EMISSION SOURCES, CONTROL OPTIONS, AND ACHIEVABLE EMISSION RATES FOR PHOSPHATE ROCK DRYERS

Source	Control options	Achievable emission rate, lb/ton
Dryer	Venturi scrubber	0.01-0.10
Dryer	Cyclonic scrubber	0.01-0.11
Dryer	Impingement scrubber	0.034
Materials handling[a]	Venturi scrubber	0.0025
Materials handling[a]	Cyclonic scrubber	0.00053-0.0014
Materials handling[a]	Impingement scrubber	0.00031
Materials handling[a]	Pulse fabric filter	0.0008-0.026

[a] Includes conveyors, screens, storage.

the dryers is usually conveyed to storage silos on weather-protected conveyors. From the silos, rock is either transported to consumers in rail cars and trucks or conveyed to grinding mills. Provision must be made to vent the conveying airstreams to and from the silos for fugitive emission control. Potential emissions from typical materials handling and storage systems are estimated at 2 lb/ton of rock handled.

Emission control options in actual use for dried rock handling and storage include both wet scrubbers and baghouses. Three designs of wet scrubbing systems were located in the state file search, and are: venturi scrubbers, impingement scrubbers, and cyclonic scrubbers. Pulse-cleaned baghouses were the only identifiable type of baghouse application on control of materials-handling. As shown in Table 2-13, all four options showed control levels less than 0.01 lb/ton, with achievable emission rates less than 0.001 lb/ton not being uncommon.

To ensure that the controlled emission rate truly reflects plant emissions requires complete and efficient capture of emissions from sources within the plant. An O&M plan is also necessary. The installation and operation of enclosures, hoods and ventilation systems have been demonstrated to reduce fugitive losses effectively within the manufacturing plant. The maintenance of these systems is a major problem in maintaining effective control of plant emissions. To ensure good operating practices requires an effective method of evaluating loss to the ambient atmosphere. An opacity standard applied to fugitive loss from the building is an effective method of maintaining control of fugitive emissions. Plants using good capture practices can reasonably be expected to maintain fugitive losses from building vents less than 5 percent opacity.

2.7.3 Control Costs

Cost estimates of the various control options presented in the previous subsection are presented in Table 2-14. Cost and emission estimates are based on a representative plant drying 200 ton/h of phosphate rock material. The process and control device characteristics incorporated into the costing estimates were derived from several existing dryers and control devices in the central Florida area. A search of state file records and plant visits were conducted to obtain the values used in cost estimates. Capital cost figures were based on values reported on permit applications on file with the State of Florida Department of Environmental Regulation and were adjusted to January 1980 dollars by use of the C-E Plant Cost Index.[3] Due to a wide range in plant designs, control device vendors, and the degree of safety factor and redundancy, it is possible that capital cost estimates may vary by ± 50 percent. The cited examples represent cases in which data was available and typical of current technology. Cost of removal per ton of product was determined by the ratio of total annualized cost and the estimated tonnage of emissions captured.

Cost estimate levels in Table 2-14 reveal small cost differences between the various control options. Apparent cost

TABLE 2-14. CONTROL COSTS OF PHOSPHATE ROCK DRYERS[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Dryer	Venturi scrubber	99.5	11	0.05	8756	244,000	10	39,710	237,940	c	31
Dryer	Cyclonic scrubber	99.5	11	0.05	8756	263,000	10	42,800	238,700	c	32
Dryer	Impingement scrubber	99.5	11	0.05	8756	459,000	10	74,700	221,300	c	34
Materials handling[d]	Venturi scrubber	99.75	2.0	0.005	1596	693,000	10	112,800	214,790	c	205
Materials handling[d]	Cyclonic scrubber	99.75	2.0	0.005	1596	224,000	10	36,500	195,880	c	146
Materials handling[d]	Impingement scrubber	99.75	2.0	0.005	1596	390,000	10	63,500	202,530	c	146
Materials handling[d]	Fabric filter	99.75	2.0	0.005	1596	560,000	10	91,130	155,870	c	155

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Data not available.

[d] Associated with dryer.

advantages for a specific control option may not necessarily represent actual cost advantages. As stated earlier, cost estimate levels may vary ± 50 percent, depending on several factors. Site-specific criteria or vendor-specific costing may override the marginal cost difference listed.

2.7.4 Recommended RACT

From the standpoint of technological feasibility, each control option is capable of attaining emission levels in the range of 0.10 lb/ton of product.

The cost of control is not a major factor since almost all plants surveyed are controlled by a control method capable of achieving the recommended emission level.

To ensure that the emissions measured by the stack test represent the controlled emission level, a fugitive emission limit applied to the plant process building in conjunction with an O&M plan is recommended. The fugitive emissions must be judged on the opacity of material escaping the building. This level is recommended to be 5 percent opacity; based on good maintenance and good hood capture, the level should be easily achieved.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of potential solubilization of phosphate material on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

2.8 PHOSPHATE ROCK GRINDING

This subsection discusses the processes used in the grinding of phosphate rock and identifies the major particulate sources within each facility. The subsection also discusses the available control technology and the cost of a typical plant using this technology. From this analysis RACT recommendations are made.

2.8.1 Process Description

Grinding is widely used in the processing of phosphate rock to pulverize the product from the rock drying process. Figure 2-19 shows a typical grinding circuit. Roller mills or ball mills are typically used to pulverize the dried product to a fine powder, usually specified as 60 percent by weight passing a 200-mesh sieve.

The roller mill is composed of hardened steel rollers that rotate against the inside of a steel ring, as shown in Figure 2-20. Ore is fed into the mill housing by a rotary valve that prevents the escape of air into the feed system. The rock is scooped up from the floor of the housing by plows and directed into the path of the rollers, where it is ground between the rollers and the steel ring. Ground rock is swept from the mill by a circulating airstream. Some product size classification is provided by the "revolving whizzers" at the top of the housing. The size of an average particle leaving the mill can be controlled by varying the speed of revolution of the whizzers. Further size segregation is provided by the air classifier,

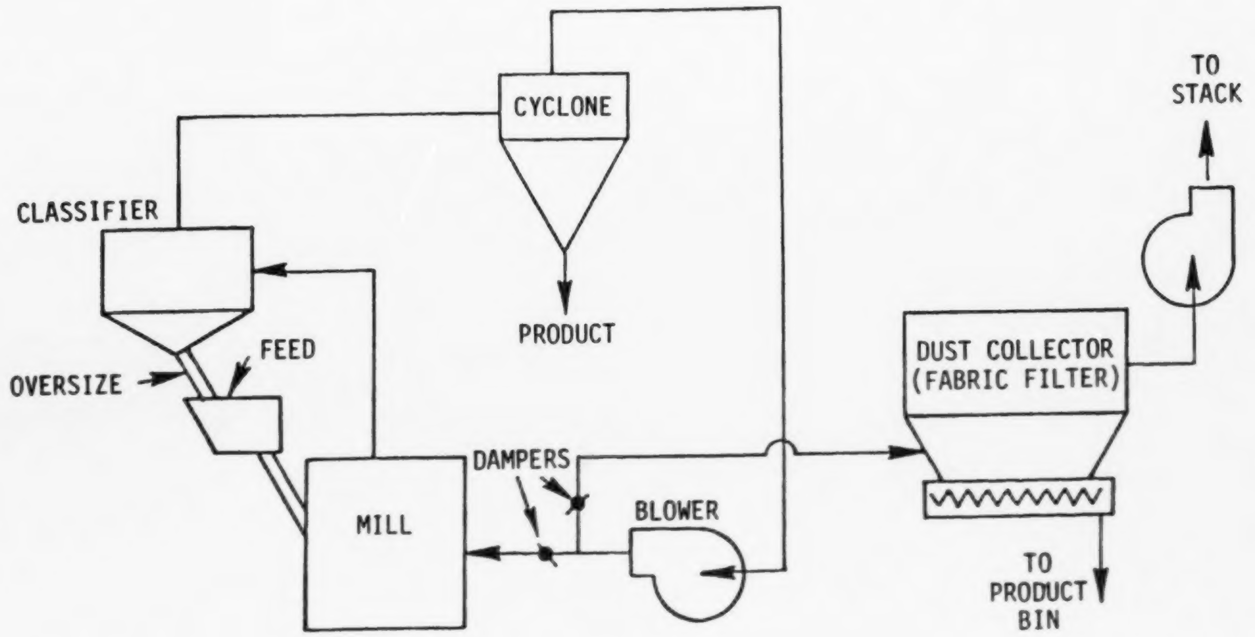

CYCLONE
CLASSIFIER
PRODUCT
FEED
OVERSIZE
DAMPERS
MILL
BLOWER
DUST COLLECTOR
(FABRIC FILTER)
TO
STACK
TO
PRODUCT
BIN

Figure 2-19. Typical phosphate rock grinding circuit.

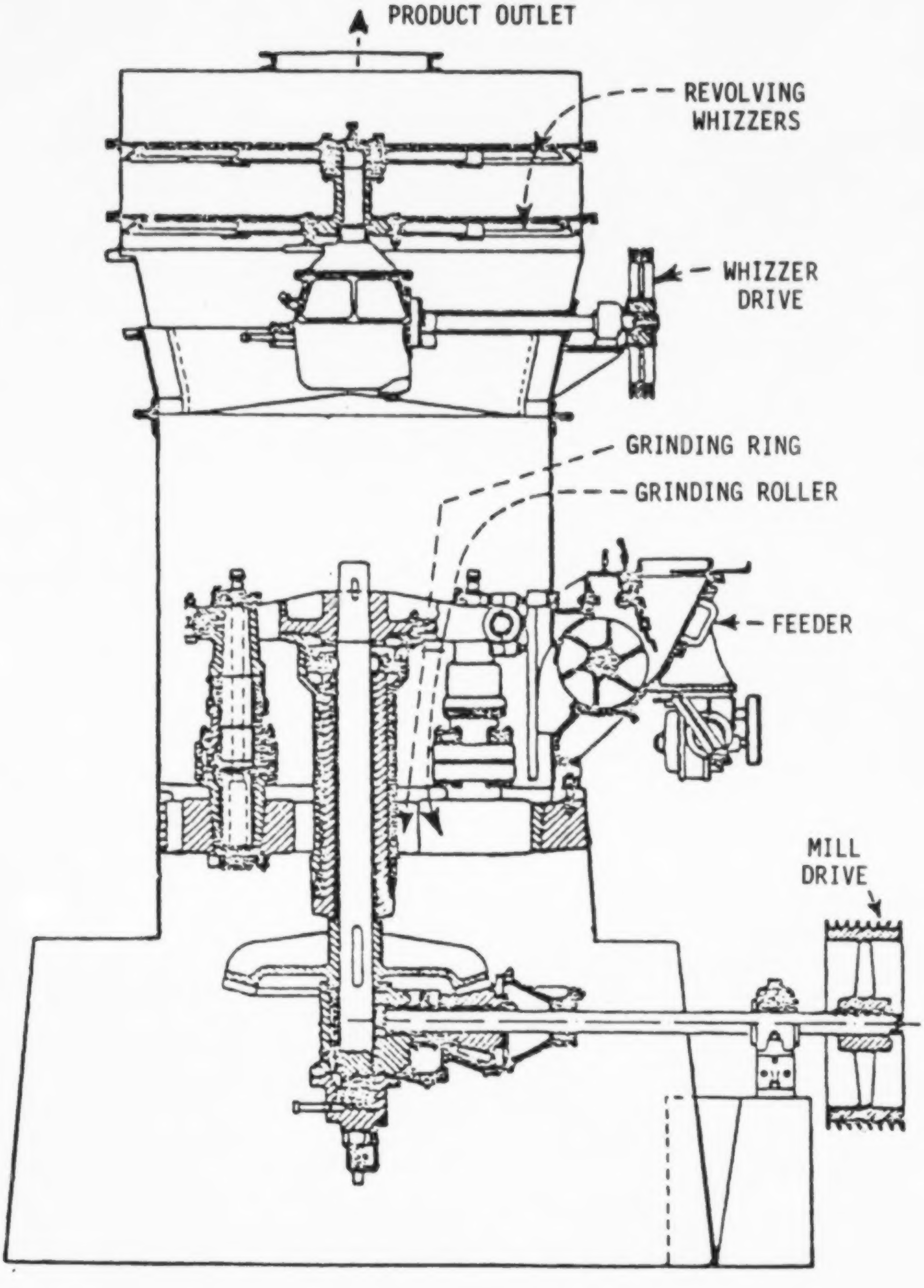

PRODUCT OUTLET
REVOLVING WHIZZERS
WHIZZER DRIVE
GRINDING RING
GRINDING ROLLER
FEEDER
MILL DRIVE

Figure 2-20. Roller mill used to grind phosphate rock.

which separates oversize particles from product-size particles and recycles the oversize portion to the mill. The product is separated from the carrying air stream by a cyclone and conveyed to ground-rock storage. The airstream is returned to the mill in a closed loop, although there is a bleed stream from the system as described below.

The ball mill is basically a drum revolving about an axis slightly inclined to the horizontal (Figure 2-21). The drum contains a large number of steel balls about 1 inch in diameter. Rock is charged into the mill through a rotary valve, ground by attrition with the balls, and swept from the mill by a circulating air stream, as described above for roller mills.

Roller and ball mills are operated slightly below atmospheric pressure to avoid the discharge of fugitive rock dust into the air. As a result, atmospheric air infiltrates the circulating streams. This tramp air is discharged from the circuit through a dust collector to the atmosphere. Mill capacities range from 15 tons/h of phosphate rock for a smaller roller mill to about 260 tons/h for a large ball mill. A typical mill has a capacity of 50 tons/h. Because roller mills are usually limited to about 75 tons/h per unit, many operators install several in parallel rather than a single large ball mill. No clear trend toward either method of grinding is evident. The volume of the tramp air discharge stream depends more on the design and operation of the grinding circuit than on

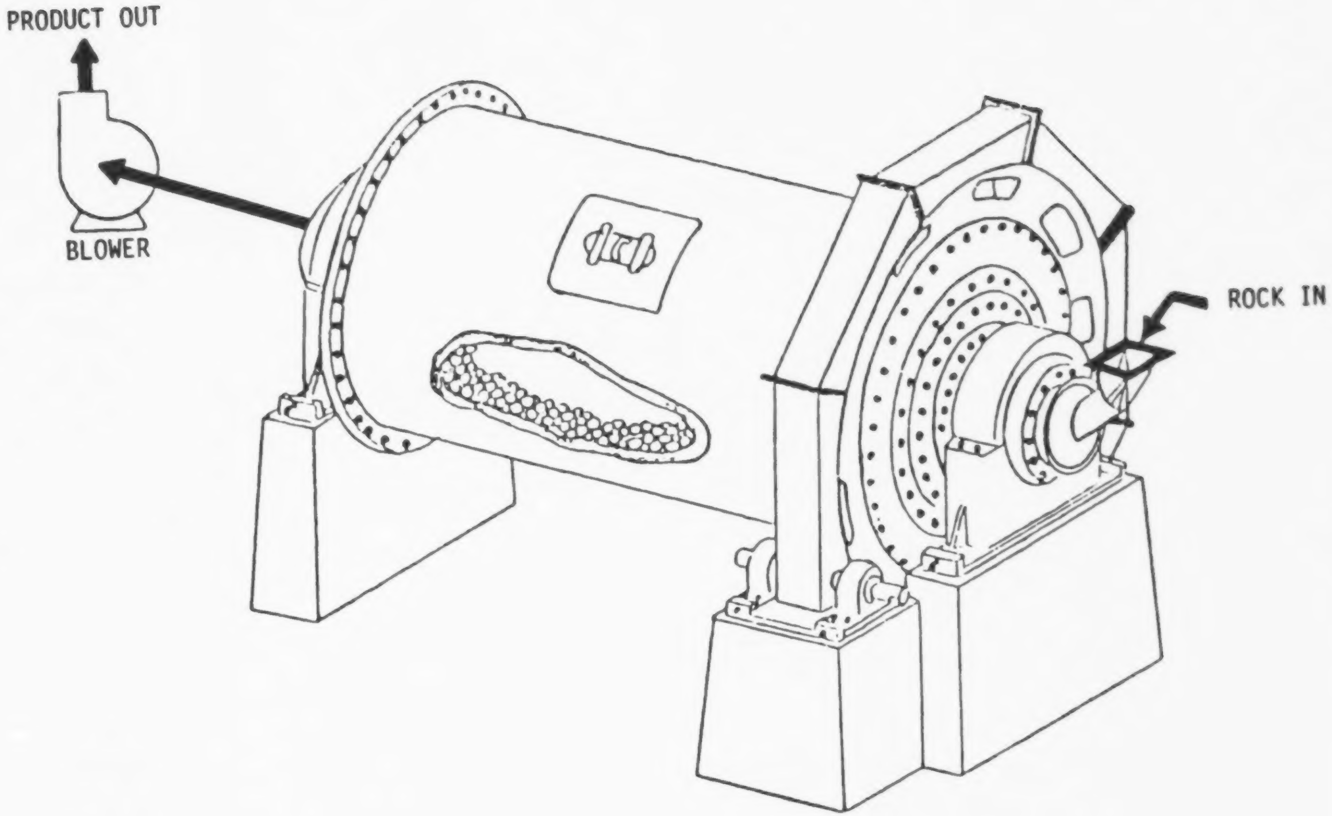

PRODUCT OUT
BLOWER
ROCK IN

Figure 2-21. Rotary ball mill used to graind phosphate rock.

the capacity of the mill. For example, it is not unusual for a 150-ton/h mill to discharge 19,000 dscfm, whereas a 250-ton/h unit might discharge 10,000 dscfm.

2.8.2 Emission Sources and Control Options

There are two major points of particulate emissions in a conventional rock grinding plant:

(1) Grinder

(2) Materials handling and storage

The characteristics of the exhaust gas from conventional grinders are given in Table 2-15. The grinder operates under a slightly negative pressure to minimize escaping gases containing ground rock dust. The system is not airtight, indicating that the drawn air must be vented and that the amount of air can vary with design and operation criteria. Grinder exhaust rates range from 1500 to 35,000 dscfm depending on process rate, and specific control rates can range from 60 to 160 dscfm per ton/h of ground rock. Grinding operations are entirely mechanical, and generate 2 to 5 grains/dscf particulate matter. For the considered representative case grinding 50 ton/h, it is estimated that 7000 dscfm of gas volume is exhausted for a reasonable operated and controlled source.

State records on phosphate rock grinders in the central Florida area indicated process rates ranging 12 to 230 tons/h. The vast majority of these grinders used fabric filter systems to control particulate emissions. Several fabric filter vendors were represented, but most fabric filters were pulse-cleaned

TABLE 2-15. CHARACTERISTICS OF EXHAUST GASES FROM PHOSPHATE ROCK GRINDERS

Exhaust flow rate	31-83 m^3/s per kg product/h (60-160 scfm per ton product/h)
Temperature	310-339 K (100°-150°F)
Moisture	Up to 9%
Uncontrolled emissions	<3.5 kg/Mg product (<7.0 lb/ton product)
Grain loading	7-11 g/dry m^3 (3-5 gr/dscf)
Dust composition	
Calcium (CaO)	45.5% by weight
Phosphorous (P_2O_5)	32.5% by weight
Silica (SiO_2)	11.0% by weight
Alluminum (Al_2O_3)	2.0% by weight
Iron (Fe_2O_3)	0.8% by weight
Magnesium (MgO)	0.7% by weight
Other	7.5% by weight

units. A minority of grinders were controlled by scrubbers; venturis were the only identifiable design type.

A review of stack test results from several grinding facilities indicated emission rates of 0.003 to 0.30 lb/ton of ground rock. Grouping of emission rates by control system type indicated that each type achieved emission rates less than 0.10 lb/ton; however, fabric filter control systems achieved rates less than 0.10 lb/ton more consistently and with greater margins (down to 0.003 lb/ton) and ease. From these results, fabric filter control of grinder exhaust is indicated to be the preferred method of particulate control.

Fugitive emissions from ground rock materials handling need to be controlled. Rock fed and discharged from the grinders is usually conveyed to storage silos on weather-protected conveyors. From the silos, rock is either transported to consumers in rail cars and trucks. Provision must be made to vent the conveying assistance to and from the silos for fugitive emission control. Potential emissions from typical materials handling and storage systems are estimated at 2 lb/ton of rock handled.

Practiced emission control options for ground rock handling and storage are limited to fabric filters. Pulse-cleaned fabric filters were the only identifiable types of fabric filters used to control emissions during materials handling. As shown in Table 2-16, fabric filter control levels were less than 0.01 lb/ton, with achievable emission rates less than 0.004 lb/ton.

TABLE 2-16. PARTICULATE EMISSION SOURCES, CONTROL OPTIONS, AND ACHIEVABLE EMISSION RATES FOR PHOSPHATE ROCK GRINDING PLANTS

Source	Control options	Achievable emission rate, lb/ton
Grinder	Pulse fabric filter	0.003-0.69
Grinder	Venturi scrubber	0.070-2.0
Materials handling (i.e., conveyors, screens, storage)	Pulse fabric filter	0.004-.0125

To ensure that the controlled emission rate truly reflects plant emissions requires complete and efficient capture of emissions from sources within the plant. The installation and operation of enclosures, hoods and ventilation systems in conjunction with a good O&M plan can effectively reduce fugitive losses within the manufacturing plant. The maintenance of these systems is a major problem in maintaining effective control of plant emissions. To ensure good operating practices requires an effective method of evaluating loss to the ambient atmosphere. It appears that an opacity standard applied to fugitive loss from the building is an effective method of maintaining control of fugitive emissions. Plants using good capture practices can reasonably be expected to maintain fugitive losses from building vents at less than 5 percent opacity.

2.8.3 Control Costs

Cost estimates of the various control options presented in the previous subsection are presented in Table 2-17. Cost and emission estimates are based on a representative plant grinding phosphate rock material at 50 tons/h. The process and control device characteristics incorporated into the costing estimates were derived from several grinders and control device cases in the central Florida area. State file records were reviewed, and plant visits were conducted to obtain the specified values used in cost estimates. Capital cost figures were based on values reported on permit applications on file with the State of Florida Department of Environmental Regulation and were adjusted to January 1980 dollars by use of the C-E Plant Cost Index.[3]

TABLE 2-17. CONTROL COSTS OF PHOSPHATE ROCK GRINDING[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Rock grinder	Venturi	99.0	5.0	0.05	990	22,500	10	3,660	105,330	c	110
Rock grinder	Pulse fabric filter	99.0	5.0	0.05	990	58,000	10	9,440	102,380	c	113
Grinding MHS	Pulse fabric filter	99.75	2.0	0.005	399	82,400	10	13,400	104,930	c	297

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Data not available.

Due to a wide range in plant designs, control device vendors, and the degree of safety factor and redundancy, it is possible that capital cost estimates may vary by ± 50 percent. The cited examples represent cases in which data were available and typical of current technology. Cost of removal per ton of product values was determined by the ratio of total annualized cost and the estimated tonnage of emissions captured.

Cost estimate levels in Table 2-17 reveal small cost differences between the various control options. Apparent cost advantages for a specific control option may not necessarily represent actual cost advantages since cost estimate levels may vary ± 50 percent. Site-specific criteria or vendor-specific costing may override the marginal cost difference listed.

2.8.4 Recommended RACT

From the standpoint of achievable emission reduction, each control option is capable of attaining emission levels in the range of 0.10 lb/ton of product.

The cost of control is not considered to be a factor since almost all plants surveyed are controlled by a control method capable of achieving the recommended emission level.

To ensure that the emissions measured by the stack test represent the controlled emission level, a fugitive emission limit applied to the plant process building is recommended. The fugitive emissions must be judged on the opacity of material escaping the building. This level is recommended to be 5 percent opacity; based on good maintenance and good hood capture, this level should be easily achieved.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of potential solubilization of phosphate material on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

2.9 LOADING RAILROAD CARS WITH PHOSPHATE ROCK

This subsection discusses the processes used in rail car loading of phosphate rock materials and identifies the major particulate sources within each facility. The section also discusses the available control technology and the cost of a typical plant employing this technology. From this analysis RACT recommendations are made.

2.9.1 Process Description

Large volumes of dried phosphate rock or ground rock products are transferred mainly by rail. After the phosphate product is dried or ground, the material is transferred to silos for short term storage. Later, it is transferred through materials handling systems to shipping areas for further processing or export.

Figure 2-22 illustrates an enclosed materials handling system for conveying phosphate rock from a storage silo to a railroad car. Four telescopic chutes are used to load material into standard rail cars equipped with four squared-shaped loading hatches. An operator lowers and positions the hydraulic-operated chutes over the rail car hatches. The telescopic

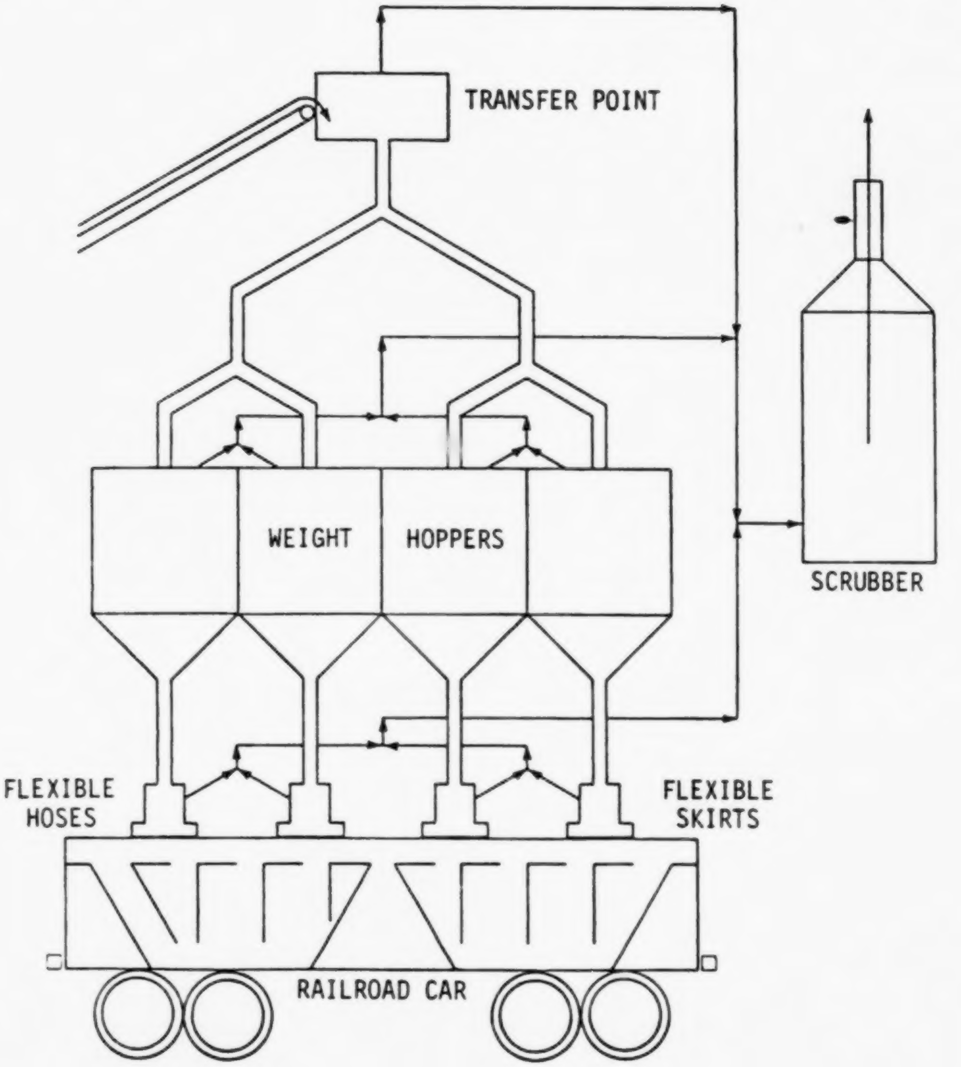

TRANSFER POINT
SCRUBBER
WEIGHT HOPPERS
FLEXIBLE HOSES
FLEXIBLE SKIRTS
RAILROAD CAR

Figure 2-22. Materials handling system for conveying phosphate rock from storage to a railroad car.

chutes are designed with flexible square-shaped skirts to enclose the hatches fully and thus prevent the escape of fugitive emissions. Flexible hoses are attached alongside of the chutes to vent the emissions generated from rail car loading to the control device.

2.9.2 Emission Sources and Control Options

The major point of particulate emissions in a conventional phosphate rock rail car loading facility is the materials handling system, including the conveyor belts and transfer points from the rock storage silo to the rail car. The volume of air required to collect the fugitive phosphate rock particles being entrained from the rail loading facility can vary from facility to facility. These emissions are ventilated from the elevator heads, transfer points, conveyor belts, and the rail car. The ventilation rate is dependent on plant age, system tightness and number of transfer points in the rock handling system. Particulate emissions from these sources are controlled with a conventional scrubber or baghouse systems, identical to the control systems used throughout the phosphate rock processing industry.

Review of stack tests from rail loadout and other phosphate rock handling and loading facilities in the central Florida area indicated emission rates of 0.0003 to 0.0125 lb/ton of material handled. The great majority of test results showed emission rates in the range of 0.0006 to 0.003 lb/ton of rock handled. Grouping of emission rates by control option categories indicated that achievement of emission levels less than 0.003 was common for each control category. Table 2-18 lists emission rates and control options gathered from source tests for phosphate rock handling and loading operations.

Characteristics of a rail loading control facility include the flexible skirt and flexible duct designs incorporated with the telescopic chute assembly. Flexible members in the control system hooding and ducting are required to accommodate the movement of the telescopic chutes, and to ensure complete capture and transfer of fugitive emissions. This type of control facility requires an operator. Complete capture of loading emissions is dependent on the operator's conscientiousness to enclose the loading hatches fully with the flexible skirt assemblies. To enclose the hatch, the operator must lower and position the skirt to cover the opened area of the hatch completely. Failure to adjust the flexible skirt onto and around the hatch will allow the escape of fugitive emissions.

To ensure that the control equipment emission rate truly reflects facility emissions requires complete and efficient capture of emissions from sources within the facility. The installation and operation of enclosures, hoods, and ventilation systems have been demonstrated to reduce fugitive losses effectively within the loading operation. The maintenance of these systems has been demonstrated to be a major problem in maintaining effective control of emissions. To ensure good operating practices requires an effective method of evaluating loss to the ambient atmosphere. An opacity standard applied to fugitive

TABLE 2-18. PARTICULATE EMISSION SOURCES, CONTROL OPTIONS, AND ACHIEVABLE EMISSION RATES FOR LOADING RAILROAD CARS WITH PHOSPHATE ROCK

Source	Control options	Achievable emission rate, lb/ton
Railroad car loading	Cyclonic scrubber	0.0009-0.004
Railroad car loading	Venturi scrubber	0.0065
Railroad car loading	Fabric filter	a

[a] Data not available.

loss from the facility is an effective method of maintaining control of fugitive emissions. Plants using good capture practices can reasonably be expected to maintain fugitive losses from building vents and rail car hatches at less than 5 percent opacity.

2.9.3 Control Costs

Cost estimates of the various control options presented in the previous subsection are presented in Table 2-19. Cost and emission estimates are based on a representative rail loadout facility handling phosphate rock at 800 tons/h. The process and control device characteristics incorporated into the costing estimates were derived from several facilities and control device cases in the central Florida area. Searching of state file records and plant visits were conducted to obtain the specified values used in cost estimates. Capital cost figures were based on values reported on permit applications on file with the State of Florida Department of Environmental Regulation and were adjusted to January 1980 dollars by use of the C-E plant cost index.[3] Due to a wide range in plant designs, control device vendors, and the degree of safety factor and redundancy, it is possible that capital cost estimates may vary by ± 50 percent. The cited examples represent cases in which data were available and typical of current technology. Cost of removal per ton of product values was determined by the ratio of total annualized cost and the estimated tonnage of emissions captured.

TABLE 2-19. CONTROL COSTS OF LOADING RAILROAD CARS WITH PHOSPHATE ROCK[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Railroad car loading	Venturi	99.75	2.0	0.005	6384	51,000	10	8,300	120,730	c	20
Railroad car loading	Cyclone	99.75	2.0	0.005	6384	58,000	10	9,400	121,130	c	20
Railroad car loading	Fabric filter	99.75	2.0	0.005	6384	145,000	10	23,600	112,840	c	21

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Data not available.

Cost estimate levels in Table 2-19 reveal insignificant cost differences between the various control options. Apparent cost advantages of a specific control option may not necessarily represent actual cost advantages. As stated earlier, cost estimate levels may vary ± 50 percent, depending on several factors. Site-specific criteria or vendor-specific costing may override the marginal cost difference listed.

2.9.4 Recommended RACT

From the standpoint of achievable emission reduction, it appears that each control option is capable of attaining emission levels in the range of 0.010 lb/ton of product. The cost of control is not a major factor since almost all plants surveyed are controlled by a control method capable of achieving the recommended emission level.

To ensure that the emissions measured by the stack test represent the controlled emission level, a fugitive emission limit applied to the plant process building is recommended. The fugitive emissions must be judged on the opacity of material escaping the building. This level is recommended to be 5 percent opacity; based on good maintenance and good hood capture, this level should be easily achieved.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of potential solubilization of phosphate material on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

2.10 SHIPS WITH PHOSPHATE ROCK LOADING

This subsection discusses the processes used in the shiploading of phosphate rock materials and identifies the major particulate sources within each facility. The subsection also discusses the available control technology and the cost of a typical plant employing this technology. From this analysis RACT recommendations are made.

2.10.1 Process Description

Large quantities of phosphate rock materials are exported for use or further processing by ship. Cost-effective transfer to foreign ports is accomplished by transoceanic tanker ships. Figure 2-23 shows a typical materials handling schematic, including materials unloading, storage, and shiploading for an export terminal.

The phosphate rock material is received by rail or truck shipments. After the material is unloaded, it is transferred through a series of weather-protected belt conveyors to storage buildings. From storage, the phosphate material is conveyed with similar equipment to the shiploader. Typical capacities of the handling systems range from 300 to 3000 tons/h of phosphate material.

The shiploading system depicted in Figure 2-24 consists of weather-protected conveying equipment, mounted on tracks to allow for movement across the full length of the stationary, docked ship. Each of several compartments in the ship are individually loaded. Before compartment loading, the telescopic

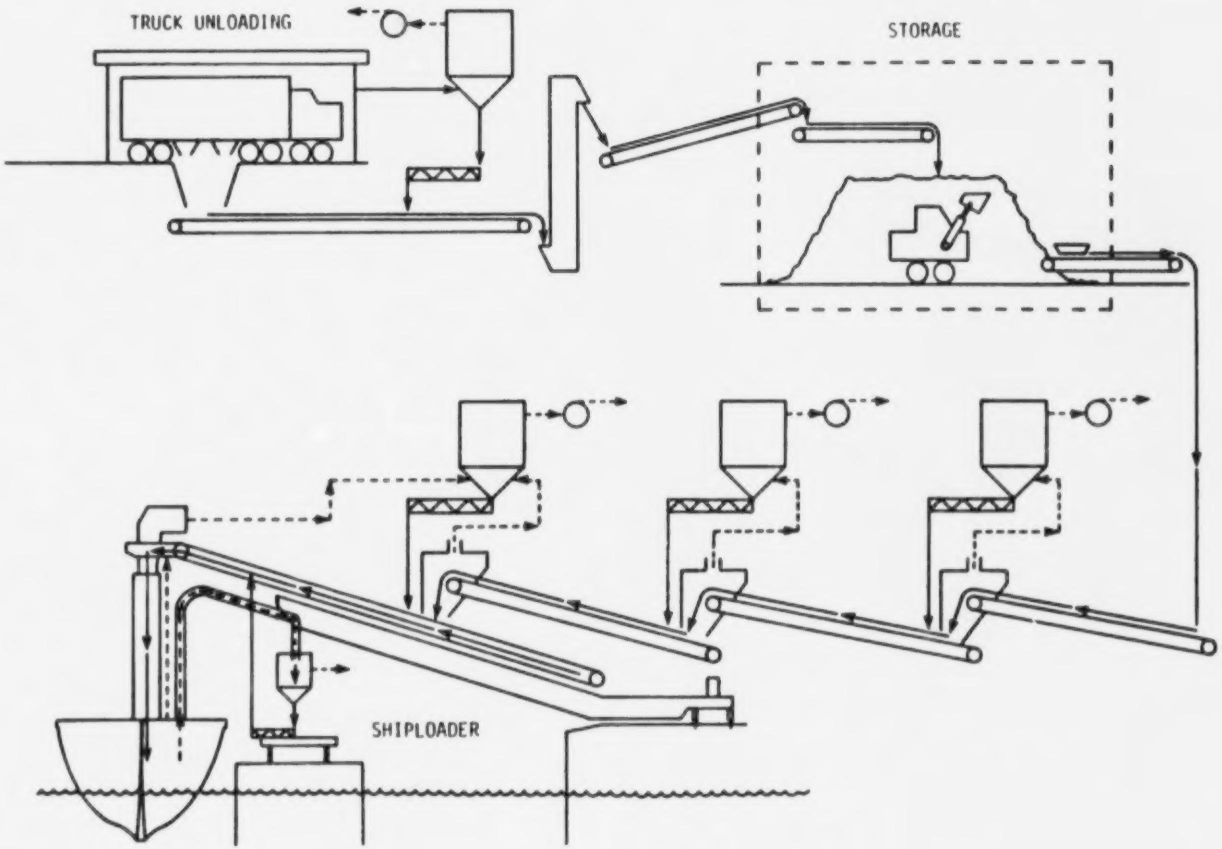

TRUCK UNLOADING
STORAGE
SHIPLOADER

Figure 2-23. Materials handling system for conveying phosphate rock and granulated fertilizer from storage to a ship.

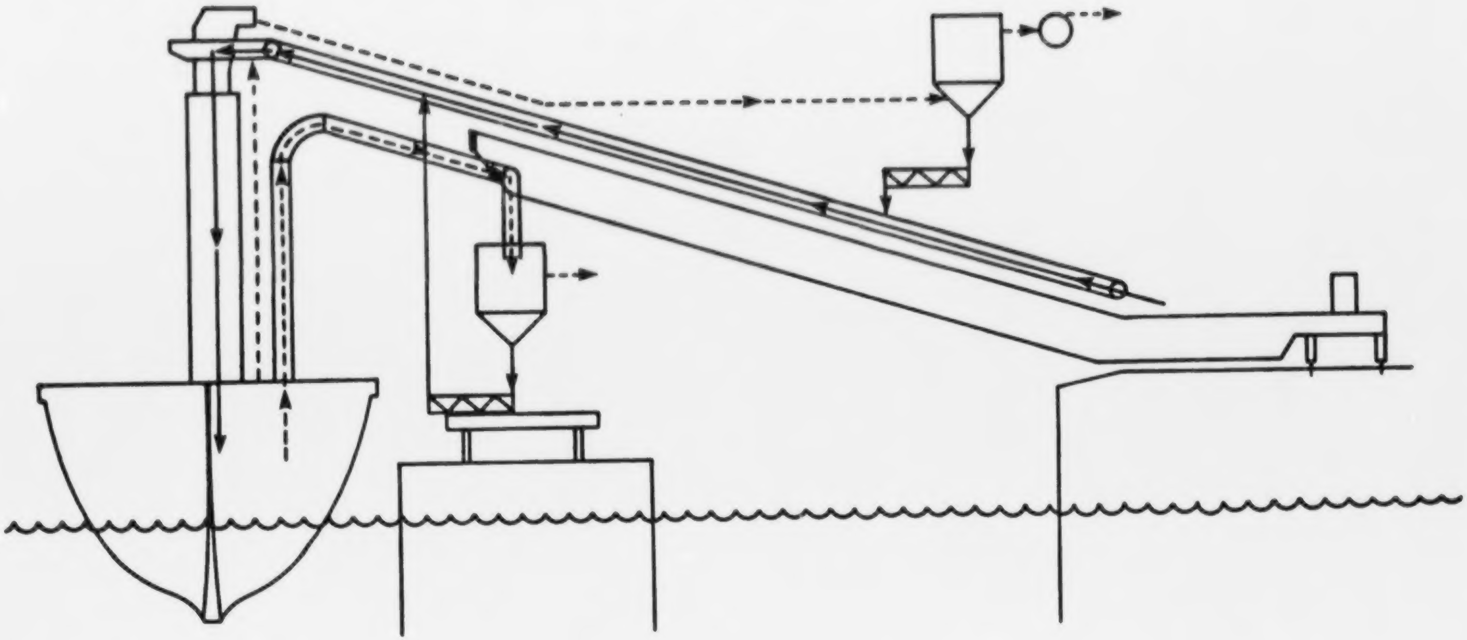


Figure 2-24. Fugitive dust collection system mounted on a movable boom above a ship.

chute is lowered several feet below the level of the deck. Several large canvases are stretched across the compartment opening and overlapped to minimize the escape of fugitive emissions. A well-designed shiploader chute has canvases attached directly to the chute assembly to minimize escaping emissions. Potential emissions from the conveyors, transfer points, and ship hold are vented through ducting to the control hardware. Shiploading capacities ranged from 800 to 3000 tons/h of phosphate material.

2.10.2 Emission Sources and Control Options

The major point of particulate emissions in a conventional phosphate rock ship loading facility is the materials handling system, including the conveyor belts and transfer points from the conveyor belt to the ship's hold tanks. The volume of air required to collect the fugitive phosphate rock particles being lost from the ship loading facility can vary from facility to facility. These emissions are ventilated at elevator heads, transfer points, conveyor belts, and the hold tanks. The ventilation rate is dependent on equipment age, tightness and number of transfer points in the rock handling system. Tightness of the system can be maximized with a good O&M plan. Particulate emissions from these sources are controlled with conventional baghouse systems, identical to the control systems used throughout the phosphate rock processing industry.

Review of source tests from ship loading facilities in the Tampa bay area indicated emission rates of 0.0001 to 0.007 lb/ton of material handled. The test results showed handling rates in the range of 800 to 3000 tons/h. All the surveyed ship loading facilities used fabric filters for control of particulate emissions. Most fabric filter systems were pulse-cleaned units; they were preferred due to advantages in cost, operation, flow handling capacity, and physical size. Well-designed control systems incorporated two fabric filters for recovering ship-loading emissions. As shown in Figure 2-24, one fabric filter system controls fugitive emissions from the conveyor belt and transfer points before the phosphate material is loaded into the ship's hold tanks. The second fabric filter system controls emissions generated during loading of the ship's tanks, through flexible ducting attached to the shiploader's telescopic chutes. Table 2-20 shows the typical control method and emission rates achieved from source tests conducted on several shiploading facilities.

TABLE 2-20. PARTICULATE EMISSION SOURCE, CONTROL OPTION, AND ACHIEVABLE EMISSION RATE FOR LOADING SHIPS WITH PHOSPHATE ROCK

Source	Control option	Achievable emission rate, lb/ton
Shiploading	Fabric filter	0.0001-.007

Characteristics of a shiploading control facility include the use of canvases and flexible ducts as an integral part of the control system. Canvases are required to minimize the escape of fugitive emissions from the hold tank during shiploading. To minimize escaping emissions further, the canvas must be attached to the telescopic chute and similarily stretched across the ship's hold tank, and overlapped with the adjacent canvases. Flexible ducting is used to accommodate movement of the telescopic chute in and out of the hold area. Capture efficiency of loading emissions is dependent on the loading crew's conscientiousness to enclose the ship's opening by using and overlapping large-sized canvases as specified in a good O&M plan. Dimensions of hold tanks vary with the different tanker ships. Use of canvas is the practical method of covering the large and various-sized tanks. Tank dimensions range from 40 to 60 feet across for both the length and width.

To ensure that the control equipment emission rate truly reflects facility emissions requires complete and efficient capture of emissions from sources within the facility. The installation and operation of enclosures, hoods, and ventilation systems effectively reduce fugitive losses within the loading operation. The maintenance of these systems is a major problem in maintaining effective control of emissions. To ensure good operating practices requires an effective method of evaluating loss to the ambient atmosphere. An opacity standard applied to fugitive loss from the facility is an effective method of maintaining control of fugitive emissions. Plants using good capture practices can reasonably be expected to maintain fugitive losses from vents and ship hatches at less than 5 percent opacity.

2.10.3 Control Costs

Cost estimates of the control method presented in the previous subsection are presented in Table 2-21. Cost and emission estimates are based on a representative facility loading phosphate rock at 1500 tons/h. The process and control device characteristics incorporated into the costing estimates were derived from several shiploading and control device cases on the Florida coast. State files were reviewed and plant visits were conducted to obtain the specified values used in cost estimates. Capital cost figures were based on values reported on permit applications on file with the State of Florida Department of Environmental Regulation and were adjusted to January 1980 dollars by use of the C-E plant cost index.[3] Due to a wide range in plant designs, control device vendors, and the degree of safety factor and redundancy, it is possible that capital cost estimates may vary by ± 50 percent. The cited examples represent cases in which data were available and thus cases typical of current technology. Cost of removal per ton of product values were determined by the ratio of total annualized cost and the estimated tonnage of emissions captured.

2.10.4 Recommended RACT

From the standpoint of achievable emission reduction, the control method is capable of attaining emission levels in the range of 0.010 lb/ton of product. The cost of control is not a major factor since almost all plants surveyed are controlled by a control method capable of achieving the recommended emission level.

TABLE 2-21. CONTROL COSTS OF LOADING SHIPS WITH PHOSPHATE ROCK[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Shiploading	Fabric filter	99.75	2.0	0.005	11,970	495,000	10	80,550	217,820	c	19

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Data not available.

To ensure that the emissions measured by the stack test represent the controlled emission level, a fugitive emission limit applied to the plant process building is recommended. The fugitive emissions must be judged on the opacity of material escaping the building. This level is recommended to be 10 percent opacity; based on good maintenance and good hood capture, this level should be easily achieved.

The test method to be used for determining the mass emission standard should be EPA Method 5.[4] The use of in-stack methods for scrubbers can yield low emission rates, because of potential solubilization of phosphate material on the filter when collected below the moisture dewpoint. Opacity should be measured by use of EPA Method 9.[5]

SECTION 3

PORTLAND CEMENT

This section discusses the processes employed in the production of portland cement, available control technology, the cost of control an finally recommended RACT. Since there is only one portland cement producer in the TSP nonattainment areas in Florida, this process description and technical analysis of control options has been limited to specifics of this plant.

3.1 PROCESS DESCRIPTION

The plant is a wet process rotary kiln operation, having three kilns with a maximum capacity of 140 tons/h clinker production rate.

The process flow consists of raw material receiving and storage, raw material grinding, calcining of slurry, clinker cooling and storage, finish cement grinding, cement storage, bagging and shipment.

The raw materials received for slurry formation are clay, koalin sand, slag and aragonite (Caribbean $CaCO_3$). The raw materials are reduced in rotary mills and fed into the kilns as a slurry.

The plant operates three kilns which are fired with pulverized coal. The coal is pulverized by Raymond Mills and is injected by solid fuel burners in the burner end of the kilns. Carbon dioxide rich gases are recycled from the kiln hoods to the mills to dry the coal and to maintain an inert atmosphere.

The calcination process consists of heating the raw materials to approximately 1800°F at which point carbonaceous materials are oxidized and alkaline components are vaporized. The calcium carbonate in the slurry is converted to calcium silicates ($CaO \cdot SiO_2$) by combination with the Silicon oxides in the sand and clay and fused to a clinker. The fusion takes place near the burner end of the kiln at a temperature between 2700 and 3000°F. The clinker is discharged from the burner end of the kilns to clinker coolers.

The entrained particulates and vaporized alkaline materials which are exhausted from the kilns are controlled by electrostatic precipitators.

The clinker at discharge from the kiln is iridescent and must be cooled before being placed in storage. The cooler consists of a moving grate on which the hot clinker is cooled. Cooling air is forced through the bed of clinker and discharged through an induced draft fan. The air entrains particulates from the clinker bed and potential emissions are as high as 20 lb/ton. The plant uses gravel bed filters to collect and separate these emissions from the gas stream.

The clinkers are placed in silo storage until they can be introduced into the finish mills. In the finish mills, the clinker is ground to a fine powder 95 percent less than 200 mesh.

The ground cement is mixed with gypsum and is classified in separators. The oversize is returned to the mills with the feed material. Particulate emissions from the conveyors, elevators, separator, and finish mills are controlled by fabric filters.

The ground cement is transferred pneumatically to finish silos for storage before bagging or bulk shipment.

For the purposes of this analysis, the general materials transport, and storage areas of the plant are discussed under the general requirements of material transfer discussed in Section 6. The kilns, clinker coolers, and finish mills are addressed in Section 3.

3.2 EMISSION SOURCES AND CONTROL OPTIONS

3.2.1 Kiln 6

Kiln 6 is a wet process kiln in which a slurry of aragonite, sand, and koalin are calcined to form a calcium-silicate clinker. The slurry (sand and koalin) is produced by rotary wet raw grind mills and pumped to the feed end of the kiln. Unground aragonite is mixed with the slurry at the feed end of the kiln. The slurry typically has a moisture content of 29 percent and a carbonate content of 76 percent ±0.2. The feed rate of dry solids is 148 tons/h and produces clinker at 73 ton/h.

Particulate emissions from the kiln are controlled by a multicyclone and an electrostatic precipitator (ESP). The control system arrangement is shown in Figure 3-1. The ESP is a Western Precipitation unit installed in 1962. The plate area is 69,984 ft^2 and at design gas volume, has a specific collection

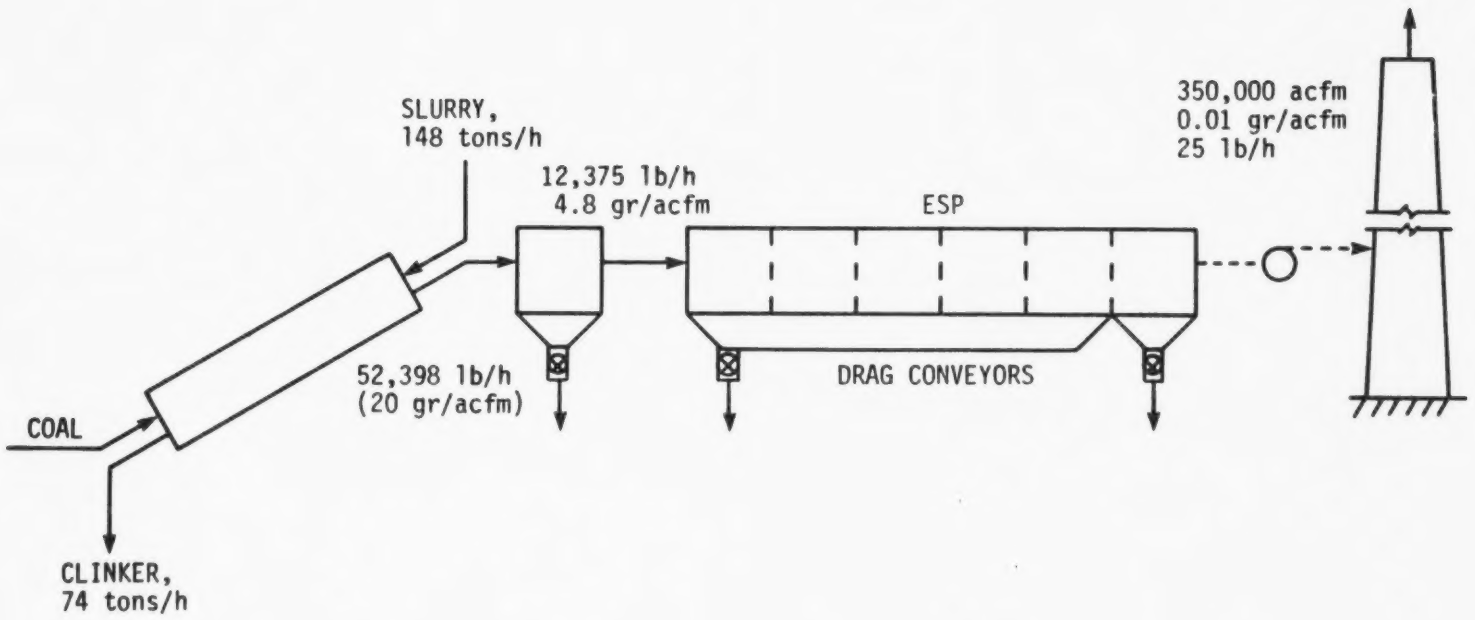

SLURRY,
148 tons/h
12,375 lb/h
4.8 gr/acfm
ESP
350,000 acfm
0.01 gr/acfm
25 lb/h
COAL
52,398 lb/h
(20 gr/acfm)
DRAG CONVEYORS
CLINKER,
74 tons/h

Figure 3-1. Control equipment arrangement at Kiln 6.

area (SCA) of 200 ft^2/1000 acfm. The superficial velocity is 4.5 ft/s. The unit has three chambers and six fields. The original design consisted of 7 T-R sets (field 1-4, 1 each; field 5, 3 units). The collected dust was discharged by three drag conveyors with removal at the inlet end.

In the past the collection of particulate in the unit has been less than that required by the regulatory agency. The company has initiated and implemented modifications to the original design to reduce the deficiencies. The inlet to the ESP has had severe gas distribution problems and, based on rapper/opacity correlations, was experiencing reentrainment from the drag chains. The plate area and power supply are within accepted design ranges for wet process kilns, but because of design problems, did not achieve the desired removal efficiency.

The changes which were made were:

1. Isolation of the number six field from the drag chains by installation of curtain and hoppers to reduce hopper sneakage and reentrainment.

2. Installation of timer sequencing of the three drag chain conveyors.

3. Installation of a primary collector before the ESP.

4. Installation of inlet turning vanes and separate nozzles for each chamber, to correct gas maldistribution.

5. Insulation of the ESP shell and hoppers.

6. Sectionalization of the fourth field with three T-R sets and the installation of additional power to fields 2 and 3.

7. Replacement of original rappers with air activated impulse rappers in all fields. The installation of peg board rapper controls in all fields.

8. Installation of digital power control circuits to provide maximum power input to all sections.

The changes incorporated into the design have allowed the kiln to achieve a mass emission rate of 25.1 lb/h. This is equivalent to 0.156 lb/ton of feed (dry solids). The inlet grain loading to the multicyclone precleaner is estimated to be 20.0 gr/acfm (52,398 lb/h).

The plant monitors the power levels of the ESP each shift and records the values in a log book. In addition, an air load test is performed on the unit each time the unit is brought down for repairs or routine maintenance. Review of operating logs indicated that the power levels have been stable for extended periods and have not deviated from the levels during the last performance test.

The kiln stack is equipped with a transmissometer and review of the strip charts indicates that the reentrainment spikes have been eliminated by the design changes. The opacity is stable between 6 and 10 percent.

The ESP is energized during kiln start up to minimize emissions. The digital controller allows the power input to be constantly maintained below the spark limit. The start up is initiated on oil firing until the ESP has achieved operating temperature (maximum power). The kiln is then changed over to pulverized coal firing and after a stable flame has been established, the kiln speed increased to maximum rate. The slurry is introduced to the kiln at programmed rate until maximum speed has been achieved. The start up time varies between 16 and 24 hs depending on the condition of the kiln.

Because of the high moisture content of flue gas from the kiln the control options available are limited. The accepted control technique for wet process kilns is a precleaner followed by an ESP. The plate area, sectionalization, power control, and power levels have increased the removal efficiency of the precipitator to a level near that of an NSPS source (0.30 lb/ton dry feed).

The opacity of the stack before moisture condensation is low, however, under certain conditions, the opacity after moisture dissipation is high (80-100 percent). The increased opacity is believed to be the result of secondary aerosol formation in the plume after moisture condensation. The aerosol is believed to be composed of sulfate or ammonium chloride radicals. The aerosol normally occurs in wet process kilns firing coal (high in nitrogen and chlorides) and having low primary particulate emission rates. More research is needed to completely quantify reactions. Because of the unpredictable character of the stack plume, the opacity which reflects the primary particulate level is in the stack. The transmissometer should be installed, calibrated and maintained in a manner consistent with part 61 of the Federal Register.

It is the opinion of the investigators that the proper maintenance and operation of the ESP can consistently maintain the emissions below 0.30 lb/ton of feed (dry solids).

3.2.2 Kilns 4 and 5

Kilns 4 and 5 are similar to Kiln 6 with the exception that the aragonite is introduced to the raw grind mills with the sand and koalin before introduction to the kilns.

Kilns 4 and 5 operate at a dry solids feed rate of 50 ton/h each and produce clinker at a rate of 25 ton/h each. The moisture content of the slurry is 29 percent and the carbonate is approximately 76 percent.

The particulate from the kilns is controlled by a Kopper's ESP. The ESP has two chambers and four fields. The plate area is 82,080 ft^2 and with both kilns operating, has a SCA of 373 ft^2/1000 acfm. The superficial velocity is 4.3 ft/s.

The ESP has four T-R sets and digital power input controls. The plates and discharge wires are rapped by electric vibrators. The collected dust is removed through eight pyramidal hoppers. The kiln stack is equipped with a transmissometer to measure plume opacity.

Based on stack test data provided by the Florida Department of Environmental Regulation, the combined emission rate of Kilns 4 and 5 can be reduced to 24.0 lb/h (0.19 lb/ton of dry feed solids).

The gas volume being handled by the unit when a single kiln is fired is less than that for which the ESP was designed. The collection efficiency is greater due to the higher SCA and lower superficial velocity.

Based on the the design of the inlet and the offset required to enter the ESP, it is suspected that the outer chamber is carrying an increased load of particulate.

It has been noted that the secondary current in Fields 2 and 3 has been supressed for an extended period (90 days log reviewed) and that the supression was not occurring during the stack testing. The reduction in secondary current indicates reduced collection efficiency. The reason for the supression is not known, but is suspected to provide complete discharge wire and plate rapping in these fields. The maintenance of continuous compliance with 0.30 lb/ton dry feed solids would require correction of this deviation in optimum power input. It is estimated that a minimum power input of 60,000 watts is necessary to comply with the proposed standard at 220,000 acfm gas volume with both kilns operating.

3.2.3 Clinker Coolers

The plant uses oscillating grate clinker coolers to cool the clinkers after discharge from the kilns. The clinker is cooled from a maximum temperature of 2700°F to approximately 350°F by forcing air through the moving bed. The cooling air removes fine particulate from the bed. Uncontrolled emission rates for oscillating grate clinker coolers are in the range of 30 lb/ton of clinker.

There are three coolers, one on each kiln. The process rates are approximately 140 tons/h (80 tons/h for Cooler 6, 30 tons/h for Cooler 4, and 30 tons/h for Cooler 5). The particulate emissions are removed from the gas stream by passing the gases through a bed of gravel. The collector arrangement at Clinker Cooler 6 is shown in Figure 3-2. The collector is divided into a number of individual compartments, each separately cleaned on a preset cycle. The collection compartment pressure drops are monitored and recorded. The gravel bed is cleaned by passing reverse-air through the bed. Stack test data provided by the State of Florida Department of Environmental regulation indicate the controlled emission rates for these systems are between 0.08 lb/ton and 0.46 lb/ton. All tests except one were below 0.20 lb/ton. It appears that the Cooler 6 control has deteriorated since installation from 0.14 to 0.46 lb/ton.

Options for particulate control include multicyclone, fabric filters, and ESP's.

3.2.4 Finish Mills

Cement is produced from clinker by grinding to 200 mesh and mixing with gypsum. The clinker is ground in rotary ball mills. The clinker is fed into the mill at one end and removed at the other end via a screw conveyor. The ground clinker is elevated to an air separator in which the particles are classified by size. The oversize is returned to the finish mills. The product is collected and transported pneumatically to finish cement silos. The finish mills are vented to remove the gas volume generated by the evaporation of water sprays used to cool the mills. The finish mill/separator fabric filter arrangement

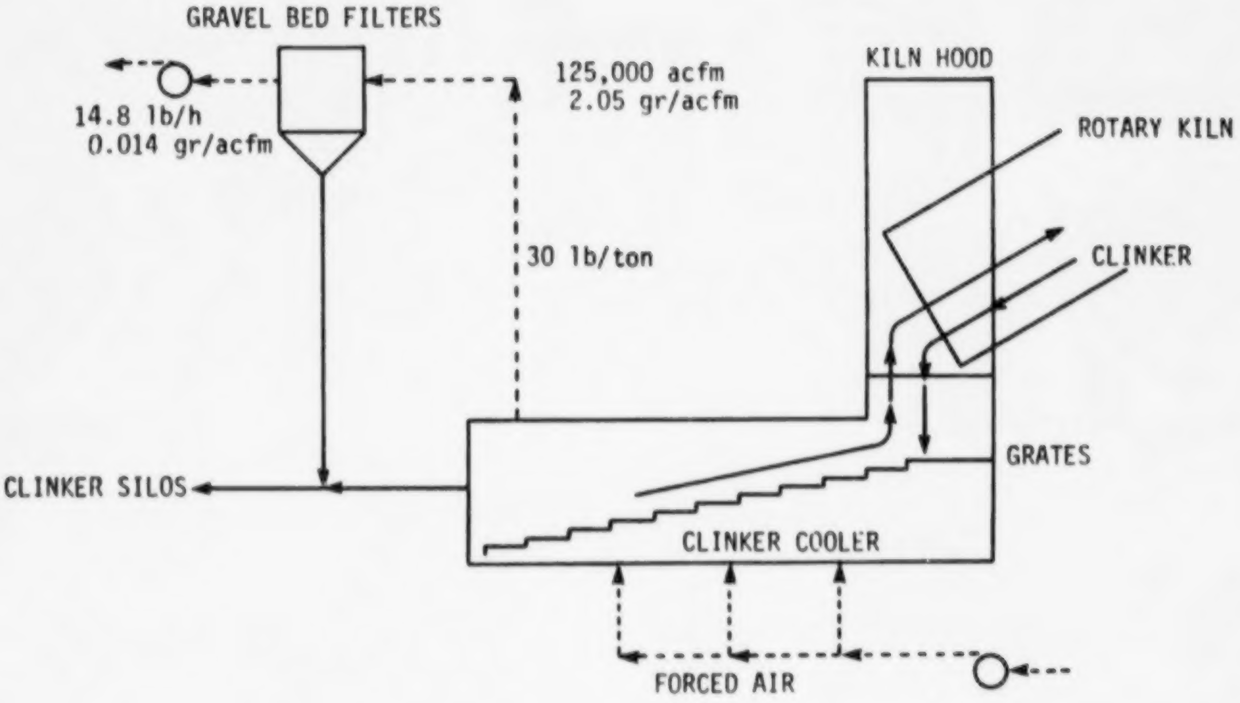

GRAVEL BED FILTERS
14.8 lb/h
0.014 gr/acfm
125,000 acfm
2.05 gr/acfm
KILN HOOD
ROTARY KILN
30 lb/ton
CLINKER
CLINKER SILOS
GRATES
CLINKER COOLER
FORCED AIR

Figure 3-2. Collector arrangement at Clinker Cooler 6.

is shown in Figure 3-3. The exhaust serves the mill and screw conveyor transporting the cement to the bucket elevator. The exhaust is approximately 13,000 acfm and contains approximately 35 gr/acfm of entrained particulate. The exhaust is controlled by a reverse-air-type fabric filter operating at an air-to-cloth design ratio of 3.64 acfm/ft^2.

The separator is exhausted to a fabric filter. The gas volume is approximately 34,000 acfm and the inlet grain loading is 35 gr/acfm. Fabric filters are the accepted method for controlling emissions from these sources. More modern plants combine the sources into a common collector. Test data on finish mills using one pulse-jet collector have demonstrated the capability to reduce the emissions to 0.015 gr/dscf.

Because of the high grain loading and abrasive nature of cement dust, the process equipment and conveying systems must be adequately ventilated and maintained to reduce fugitive emissions. The proper operation and maintenance of the system should reduce the fugitive emissions to a level at which visible emissions from the finish mill building can be maintained below 5 percent opacity.

3.3 CONTROL COSTS

The estimated cost of the control methods discussed in the previous sections is presented in Tables 3-1, 3-2, and 3-3. The cost is based on data supplied by the Company and typical values for the industry.

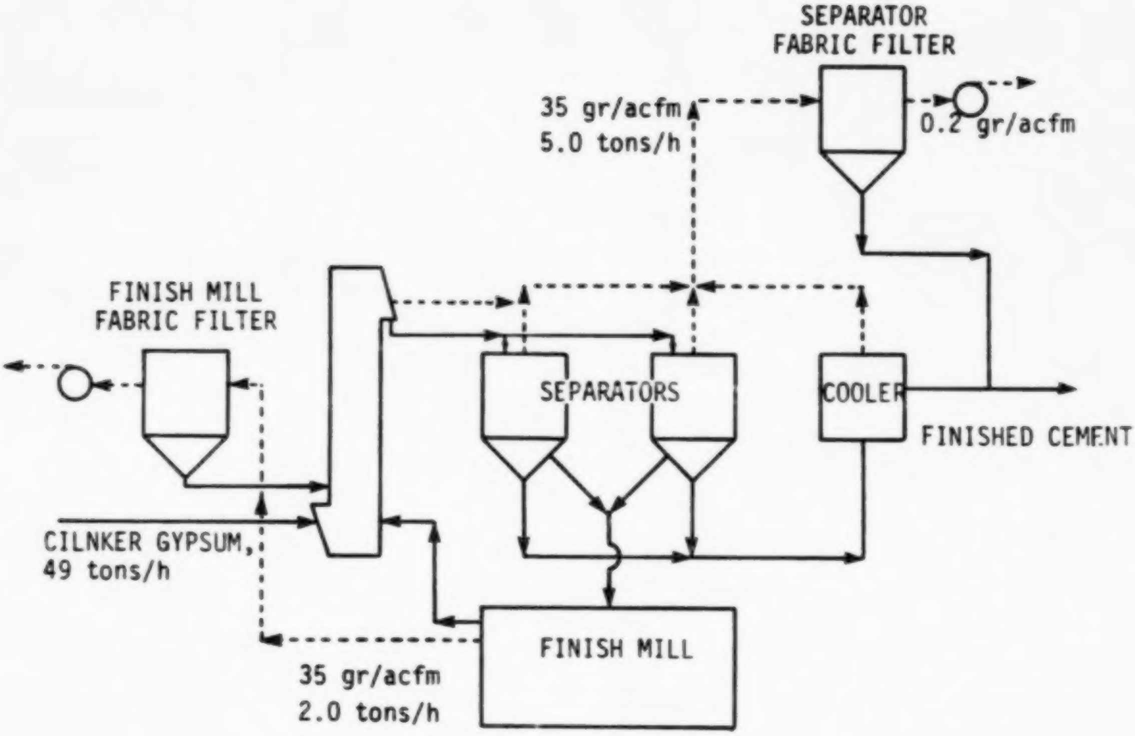

SEPARATOR
FABRIC FILTER
35 gr/acfm
5.0 tons/h
0.2 gr/acfm
FINISH MILL
FABRIC FILTER
SEPARATORS
COOLER
FINISHED CEMENT
CILNKER GYPSUM,
49 tons/h
FINISH MILL
35 gr/acfm
2.0 tons/h

Figure 3-3. Finish mill/separator fabric filter arrangement.

TABLE 3-1. CONTROL COSTS OF CEMENT KILNS[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Kilns 4 and 5	ESP	99.2	302.7	0.23	123,988[c]	745,000	20	87,507	144,908	d	2
Kiln 6	Mechanical collector, ESP	99.95[e]	354	0.19	205,592[f]	1,000,000	20	117,460	527,472	d	3

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[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Based on operation for 8000 h/yr at dry feed rate of 102 tons/h.

[d] Product recovered is not currently being returned to the kilns.

[e] Mechanical collector is 76 percent efficient; ESP is 99.8 percent efficient.

[f] Based on operation for 8000 h/yr at dry feed rate of 148 tons/h.

TABLE 3-2. CONTROL COSTS OF CEMENT CLINKER COOLERS[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits	
Clinker cooler 4	Multiclone	85	30	4.5	3060[d]	50,000	10	8,136	41,685	133,171	(27)
Clinker cooler 4	Fabric filter	99	30	0.30	3564[d]	558,000	10	90,803	154,053	155,105	25
Clinker cooler 4	Gravel bed	99.3	30	0.20	3576[d]	500,000[e]	10	55,000	107,884	155,627	2
Clinker cooler 5	Multiclone	85	30	4.5	3060[d]	50,000	10	8,136	41,685	133,171	(27)
Clinker cooler 5	Fabric filter	99	30	0.30	3564[d]	558,000	10	90,803	154,053	155,105	25
Clinker cooler 5	Gravel bed	99.3	30	0.30	3576[d]	500,000[e]	10	55,000	107,884	155,627	2
Clinker cooler 6	Multiclone	85	30	4.5	7548[f]	80,000	10	13,018	62,603	328,488	(33)
Clinker cooler 6	Fabric filter	99	30	0.30	8791[f]	1,250,000	10	203,412	223,519	382,584	5
Clinker cooler 6	Gravel bed	99.3	30	0.30	8820[f]	1,000,000	10	110,000	195,123	383,846	(8)

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Based on 80 percent of finished cement value of $54.40/ton. Source: Material Prices, Engineering News Record, 205(10):36-37, September 1980. (Mill price Alabama.)

[d] Based on operation for 8000 h/yr at 30 tons/h.

[e] Estimate.

[f] Based on operation for 8000 h/yr.

TABLE 3-3. CONTROL COSTS OF CEMENT FINISH MILLS[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $			Cost of (credit for) removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	Credits[c]	
Finish mill separator	Fabric filter	99	10,200[e]	5.82[f]	40,776	306,000	10	49,801	113,386	2,218,214	(51)
Finish mill	Fabric filter	99	3,900[e]	2.2[f]	15,591	117,000	10	19,039	93,580	848,150	(47)

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

[c] Based on finished cement price of $54.40/ton. Source: Material Prices. Engineering News Record, 205(10):36-37, September 1980. (Mill price Alabama.)

[d] Each mill requires two collectors. Four finish mills are operted at the plant.

[e] Based on 35 gr/acfm.

[f] Based on 0.02 gr/acfm.

3.3.1 Kilns

The cost of particulate removal in kiln operations is based on power input to the ESP required, fan horsepower, maintenance costs, and capital charges. The cost of achieving the standard is not directly related to the mass emitted because the basic structure (plates, shell, etc.) are in place. The difference in achievable mass emission rates is related directly to the available power input.

The changes incorporated by the company have been successful in allowing the continuous power levels necessary to achieve the standard at other times than that required for performance tests. The cost of control for the two ESP's is different because of the difference in power inputs, gas volume, and SCA. The values, however, are comparatively low for particulate removal.

3.3.2 Clinker Coolers

The method of controlling clinker coolers at the plant is by gravel bed filtration. For comparison the costs of control of fabric filters and multicyclones have been provided.

The last cost option is the multicyclone. The lower cost is reflected in lower pressure drop and maintenance costs. The highest cost is fabric filters. This is caused by the higher maintenance cost and capital investment required. The method chosen by the plant is lower in cost than fabric filtration even though the system has a higher pressure drop.

The value of recovered clinker has been calculated in the cost/ton removed and this credit substantially reduces the anualized cost.

3.3.3 Finish Mills

The finish mill collectors used at the plant are fabric filters. Since the product must be recovered in a dry state and has market value, the accepted control method is fabric filters irrespective of cost.

The annualized cost estimates include the value of recovered product. The credit for this recovery substantially reduces the annualized cost.

3.4 RECOMMENDED RACT

Based on the design and operation of the ESP serving the cement kilns, it is the opinion of PEDCo that the units are capable of achieving an emission limit of 0.30 lb/ton dry feed on a consistent basis. The opacity as measured in the stack can be consistently maintained below 20 percent.

The control devices employed to control emissions from the clinker coolers have demonstrated the ability to achieve an emission level of 0.20 lb/ton of clinker. The cost of control appears to be less than that of fabric filtration but substantially higher than mechanical methods. Observation of the stacks indicates that the opacity can be maintained below 20 percent.

The finish mills are used to grind the cement clinker and produce the market product. The collected particulates are returned to the process and typically represent 20 percent of the mill's throughput. The recovery of the material is necessary for economic operation of the process.

The proper maintenance and operation of fabric filters on the mill and separator exhausts as specified in an O&M plan can reduce the outlet loading to 0.02 gr/acfm.

The cost of recovery of the dust is low compared to the value of the material. The proper operation of the enclosures, hoods, and ventilation system is necessary to collect the dust from the mill, separator, elevator, and conveyors. The proper use of the system can consistently maintain the fugitive dust level from the finish mill enclosure below 5 percent opacity.

To ensure proper maintenance of the fabric filters and provide continuous compliance with the mass standard, an opacity limit of 5 percent is required. The mass standard cannot be achieved if an opacity of less than 5 percent is consistently observed.

SECTION 4

ELECTRIC ARC FURNACES

This section describes the operation, emission sources, control options and costs, and reasonably available control technology (RACT) for electric arc furnaces.

4.1 PROCESS DESCRIPTION

Electric arc furnaces are widely used to produce steel. Figure 4-1 presents a schematic of a typical electric arc furnace. Furnace operation is initiated by swinging the furnace roof aside to permit charging of the furnace with scrap steel. After charging, the roof containing carbon electrodes is returned to the top of the furnace and the electrodes are moved down into the scrap. Electric power is then introduced to the electrodes to heat and melt the charge of scrap steel. By alternate charging and melting, the furnace eventually is filled to its capacity with molten steel. Lime is also added with the scrap steel charges to act as a flux in removal of impurities present in the scrap.

When the charging and melting is completed, the composition of the melt is modified as desired in a refining operation in which alloying agents such as ferromanganese, silicon manganese, and ferrosilicon are added. The refined melt is then tapped

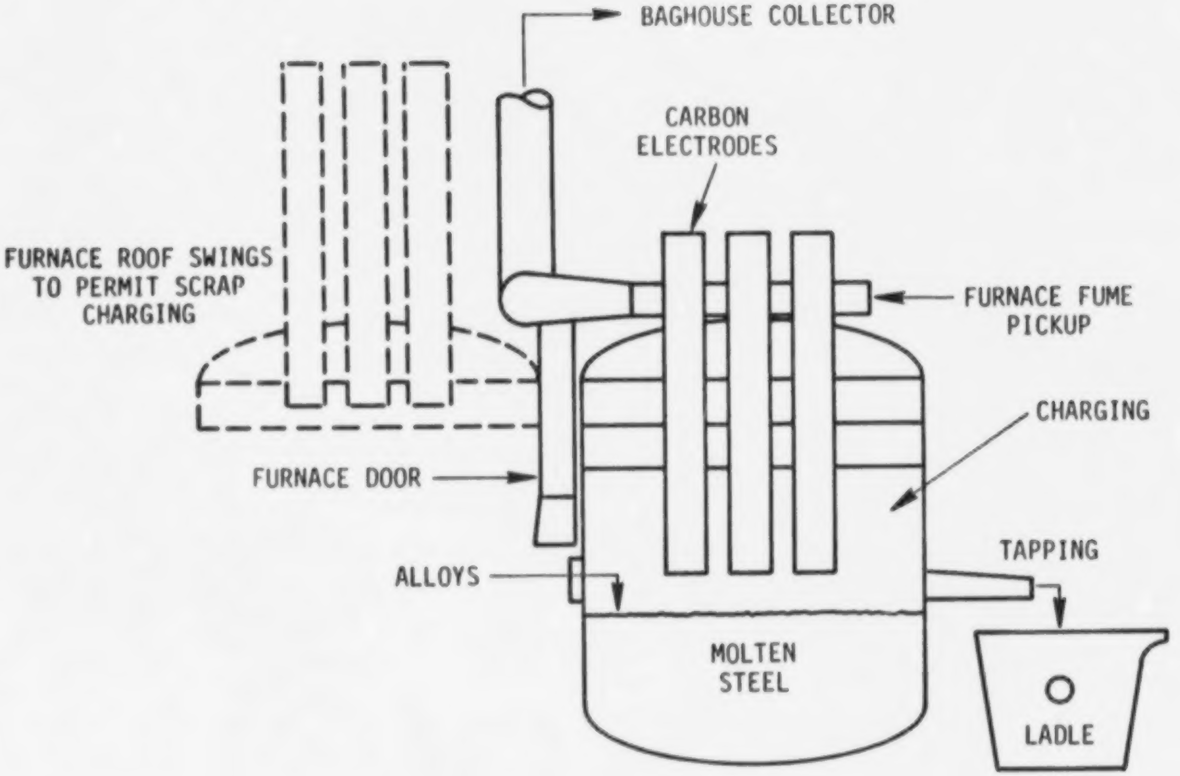
BAGHOUSE COLLECTOR
CARBON ELECTRODES
FURNACE ROOF SWINGS TO PERMIT SCRAP CHARGING
FURNACE FUME PICKUP
CHARGING
FURNACE DOOR
TAPPING
ALLOYS
MOLTEN STEEL
LADLE

Figure 4-1. Electric furnace for steel making.

from the furnace into ladles which are taken by crane to an adjoining work area when the melt is poured into an appropriate mold for shaping and solidification into the final desired steel product. After discharge of the melt, the furnace is cooled for refractory lining repair if needed before another cycle of scrap charging and melting is repeated.

Furnace capacities vary from as small as one ton to as much as several hundred tons and the length of a furnace cycle (as measured from tap to tap) varies as a function of furnace capacity and electric power input.

4.2 EMISSION SOURCES AND CONTROL OPTIONS

Particulate emissions from an electric arc furnace occur throughout the cycle but are particularly noticeable during the charging and tapping steps of operation. The particulate emissions consist in large part of metal oxides and are usually small in size (i.e., less than 10 micrometers diameter). The amount of emissions varies from 4 to 40 lb/ton of produced steel. The quantity depends upon the cleanliness and type of scrap employed, the manner of scrap charging to the furnace, and the method of tapping. An average uncontrolled level of 10 lb/ton of steel produced is representative for the industry.

Several options of control exist for particulate emissions with respect to the control device used and the collection configuration employed. These options are outlined in Table 4-1. As can be noted from the table, the use of a canopy plus ductwork at the furnace venting to a fabric filter is the option that has the advantage of both good capture and removal efficiencies.

TABLE 4-1. PARTCULATE EMISSION CONTROLS FOR ELECTRIC ARC FURNACES

Control option	Comments
Emissions capture	
Direct evacuation at furnace roof	Does not capture emissions during charging and tapping
Direct evacuation plus canopy hood over arc-furnace	Commonly used
Total Building Evacuation	Normally used for small buildings only or where a large number of sources exist in building
Control device	
Electrostatic precipitator	Not commonly used because gas stream conditioning is required
Fabric filter	Commonly used because of inherent high efficiency
High-energy scrubber	Rarely used because capture of small particles is difficult

4.3 CONTROL COSTS

Representative costs for the use of the various dust control devices are presented in Table 4-2 for a canopy and direct evacuation configuration of dust collection. The canopy and direct evacuation method of gas collection is recommended as it is the most widely employed configuration in the industry. As shown by the costs in Table 4-2, the fabric filter is the most economic control device with respect to both capital investment and direct operating cost. The use of a high energy scrubber is penalized at the high control efficiency required by the proposed regulation both by the high energy level required and by the difficulty of fine particulate capture. The use of an ESP for control requires gas conditioning and a large plate area to comply with the emission level proposed. By comparison, a fabric filter has an inherently high capture efficiency for fine particulate matter and the gas needs no preconditioning for efficient filter operation.

4.4 RECOMMENDED RACT

On the basis of the relative investment and operating costs required and its widespread employment in the industry, the use of a fabric filter with a canopy and direct evacuation collection system is the recommended RACT for the control of particulate emissions from an electric arc furnace producing steel.

A fabric filter on an electric arc furnace can reasonably be expected to reduce emissions from the control device to the level

TABLE 4-2. CONTROL COSTS OF A TYPICAL ELECTRIC ARC FURNACE PRODUCING STEEL[a]

Source of emissions	Control options	Control %	Emissions			Total capital cost, $	Expected life, yr	Cost, $		Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	
Electric arc furnace	Electrostatic precipitator	99.9	10	0.01	8392	4,500,000	10	732,375	480,000	144
Electric arc furnace	High-energy venturi scrubber	99.9	10	0.01	8392	4,100,000	10	667,275	1,000,000	199
Electric arc furnace	Fabric filter	99.9	10	0.01	8392	3,400,000	10	565,335	330,000	107

[a] Cost in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

of 0.006 gr/dscf at a reasonable cost. In addition, the use of a canopy over the furnace should permit capture such that there should be no visible emissions from the building openings except during charging and tapping periods. Therefore, it is recommended that no visible emissions be permitted from the building openings except during charging and tapping periods when a higher opacity would be permitted.

Emissions from the control device should be measured by use of EPA Method 5,[4] and opacity should be measured by use of EPA Method 9.[5]

SECTION 5

SWEAT OR POT FURNACES

This section identifies the major particulate sources from sweat or pot furnaces. Also discussed are the available control technology and the cost of a typical plant employing this technology. From this analysis, RACT recommendations are made.

5.1 PROCESS DESCRIPTION

Sweat or pot furnaces are used to melt metals which have melting temperatures less than 1400°F. Furnace capacities range from 1 to 50 tons and are usually indirectly heated by gas firing. As employed in melting and sweating practice, the furnace is cylindrical in shape and is built of refractory-lined steel or iron.

Sweating, as applied to metallurgical practice, is the procedure whereby a material containing metals of different melting points is heated to liquify the metal of lower melting point and thus separate it from the higher melting metal. Lead is commonly recovered from scrap metal and storage batteries by this procedure.

The furnace process for melting consists of the sequential steps of charging the pot with solid metal, heating and melting the charge, adjusting its composition as required, and then discharging it from the furnace in liquid form into a ladle for transport to a casting operation. Lead, zinc, bismuth, and antimony are among the metals that are processed in this manner.

5.2 EMISSION SOURCES AND CONTROL OPTIONS

Particulate matter in the form of metal and metal oxides are emitted from the mouth of the furnace especially during charging and tapping operations. The emissions are a function of the composition of the charged materials and of the furnace temperature. The particulate emissions are characteristically small in diameter, 10 microns or less, and range from 0.1 to 14 lbs/ton of metal processed.

Because of the relatively small size of the furnaces used, total enclosure of the top of the furnace is easily accomplished, thus ensuring effective capture of particulate matter, especially charging and tapping. Captured particulates can be removed by scrubbing or by the use of a fabric filter. The use of an ESP is impractical since the gas flows involved are small, 20,000 cfm or less. Of the two options available for control, fabric filters are more widely used for particulate emission control than are venturi scrubbers.

5.3 CONTROL COSTS

Investment and direct operating costs for scrubber and fabric filter systems are presented in Table 5-1 for several gas flow rates. The data shows that for systems in this range, fabric filter systems are less expensive to install and operate

TABLE 5-1. CONTROL COSTS OF A TYPICAL SWEAT OR POT FURNACE[a]

Source of emissions	Control options	Control, %	Flow rate, scfm	Emissions			Total capital cost, $	Expected life, yr	Cost, $		Cost of removal, $/ton
				Uncontrolled, lb/ton	Controlled, lb/ton	Removal, tons/yr			Annual capital[b]	Annual O&M	
Furnace	High-energy wet scrubber	99	10,000	10	0.1	1782	555,000	10	90,330	88,000	100
Furnace	High-energy wet scrubber	99	20,000	10	0.1	3564	691,000	10	112,460	108,000	62
Furnace	High-energy wet scrubber	99	32,500	10	0.1	5792	805,000	10	131,000	124,000	44
Furnace	Fabric filter	99	10,000	10	0.1	1782	273,000	10	44,430	27,000	40
Furnace	Fabric filter	99	20,000	10	0.1	3564	441,000	10	71,770	43,000	32
Furnace	Fabric filter	99	32,500	10	0.1	5792	592,000	10	96,348	60,000	27

[a] Costs in January 1980 dollars.

[b] Based on a 10 percent cost of capital.

than are venturi scrubber systems. The auxiliary equipment required for slurry and water handling in a scrubber system are responsible for the higher capital investment. The higher operating costs for a scrubber are due to electric power requirements of the system for removal of fine particulate matter. By contrast, a fabric filter has an inherently high collection efficiency and has modest utility requirements.

5.4 RECOMMENDED RACT

The use of a fabric filter with a complete enclosure of the top of the pot furnace is the recommended RACT. This recommendation is based upon its relative economy and widespread use in industry.

Since a fabric filter can reasonably be expected to reduce emissions by 99 percent at a reasonable cost, a RACT emission limit of 0.05 gr/dscf from the control device should be attainable by sweat or pot furnace sources. In addition, the use of complete enclosure of the top of the furnace should control emissions such that there should be no visible emissions from building openings. It is also recommended that emissions from the control device be measured by use of EPA Method 5,[4] and that opacity be measured by use of EPA Method 9.[5]

SECTION 6

MATERIALS HANDLING, SIZING, SCREENING, CRUSHING, AND GRINDING OPERATIONS

This section discusses the general processes employed in material handling, sizing, screening, crushing and grinding operations and an estimate of emissions from these sources. Also discussed is the available control technology and the cost of employing this technology. From this analysis, RACT recommendations are made.

6.1 PROCESS DESCRIPTION

Materials handling begins upon receipt of a particular raw material commodity and continues through operations of crushing, classifying, grinding, and storage, and culminates in the shipment of a final product. The type and sequence of process operations vary according to the specific commodity to be handled. Products handled include but are not limited to cement, clinker, fly ash, coke, gypsum, shale, lime, sulfur, phosphatic materials, slag, and grain or grain products. Figure 6-1 is a simplified flow diagram of materials handling operations.

Raw material unloading operations frequently associated with materials handling include: dumping by trucks; crane-clamshell and bucket ladder removal from vessels; and side, rotary, or bottom dumping from railcars. Depending upon the nature of the

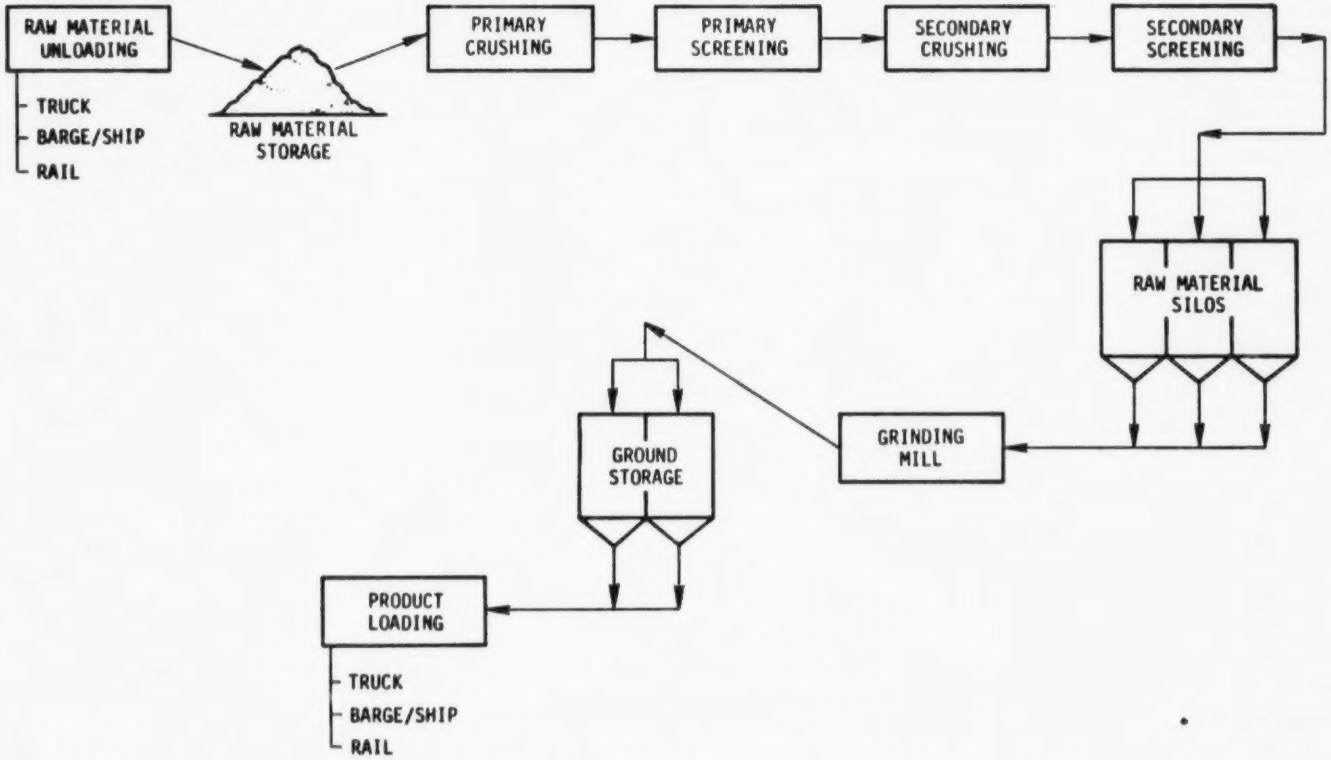
RAW MATERIAL UNLOADING
TRUCK
BARGE/SHIP
RAIL
RAW MATERIAL STORAGE
PRIMARY CRUSHING
PRIMARY SCREENING
SECONDARY CRUSHING
SECONDARY SCREENING
RAW MATERIAL SILOS
GRINDING MILL
GROUND STORAGE
PRODUCT LOADING
TRUCK
BARGE/SHIP
RAIL

Figure 6-1. Simplified flow diagram of materials handling operations.

raw material, initial stockpiling may be open or enclosed. Transfer and conveying of materials is usually accomplished through use of belt or screw conveyors, bucket elevators, or vibrating conveyors and pneumatic equipment. Primary crushers are often jaw or gyratory crushers, set to act upon rocks larger than about six inches and to pass smaller sizes. Depending on the ultimate size requirements of the product, material from the primary crusher may be screened with the undersize going directly to the screening plant and the oversize to secondary crushing, or all material from primary crushing may be routed to the secondary crusher. Secondary crushers are often of the cone or gyratory type. The material at this point may either be conveyed to open storage or transferred to silos or enclosed bins. Grinding, which reduces the material to specification product size, is commonly conducted through use of ball or hammermills. For example, in gypsum processing, finish grinding of rock, which reduces the size to approximately 100 mesh, is accomplished almost exclusively by hammermill. For gypsum though, the mineral is then sent on to vertical kilns or kettles for calcination and further processing to meet the desired product specifications. Final product is stored to await bulk shipment by either rail, vessel, or truck.

6.2 EMISSION SOURCES AND CONTROL OPTIONS

There are six major points of particulate emission in general material handling:

(1) Unloading

(2) Conveying and transfer

(3) Storage

(4) Crushing and grinding

(5) Screening and sizing

(6) Loadout

Because the proposed regulation covers the handling of numerous materials, the control options discussed are general in nature. Control methods available for reducing fugitive emissions from material handling activities are specific to the site of emissions (i.e, the site of unloading) during conveying and at points of transfer. Therefore, discussions of controls and later of control costs are addressed by the individual sites of dust generation. Table 6-1 summarizes the available control options.

The minimization of dust from unloading activities can be accomplished through the total or partial enclosure of the unloading facility and the removal of the particulate to a bag filter system, an enclosure without a fabric filter system, or a water or chemical spraying system.[8,9]

The control of fugitive dust from truck dumping activities can be accomplished with either the enclosure or spray system techniques. The application of control practices to truck dumping sites are dependent largely on the industry or material involved. A 90 to 95 percent reduction of fugitive dust from truck dumping activity can be accomplished when the site is enclosed and the captured particulate is vented to a control

TABLE 6-1. PARTICULATE EMISSION SOURCES AND CONTROL OPTIONS FOR MATERIALS HANDLING

Source	Control option
Unloading	Partial enclosure, total enclosure/vent to a fabric filter, water/chemical spray
Conveying and transfer	Partial enclosure, total enclosure/vent to fabric filter, water/chemical spray
Storage (in structure)	Controls on transfer of material, enclosure, enclosure/vent to fabric filter, water spray
Screening and sizing	Enclosure, enclosure/vent to fabric filter
Loadout	Partial enclosure, total enclosure/vent to fabric filter, water spray

device.[9] A 50 percent control efficiency can be achieved with a water spray system.[9]

Fugitive dust emissions can be controlled through the enclosure of rail car unloading stations accompanied by dust collection with bag filters. This method of control can effectively reduce 99 percent of the fugitive dust. Depending on the type of material involved, fugitive dust from rail car unloading operations can also be controlled using spray systems. This measure results in an effective control efficiency of 80 percent. The use of chemical stabilizers may improve the efficiency of this control measure. The addition of chemicals to the spray system, however, increases the cost of operation. The control of dust from conveying and transfer operations can be accomplished through methods similar to those used during unloading operations. Conveying or transfer emissions can be minimized through the use of enclosures or spray systems. Enclosure of conveying systems can be either partial (top) or total. The control efficiency of a partial enclosure system is rated at 80 percent. The total enclosure of a conveying system, which includes the use of a dust collection system (e.g., bag filter) can result in a control efficiency increase to 95 percent.

Transfer stations located along the course of a conveying operation can be significant sources of fugitive dust. The control of dust from these sources is also accomplished using enclosures. The total enclosure of a transfer point can effectively reduce fugitive emissions by 70 percent. The addition of a bag filter to a transfer point enclosure can raise the control efficiency to approximately 99 percent. Effective control of dust from transfer stations can also be accomplished using water and chemical spray systems. The spray system has an added advantage in that the aggregate subject to chemical spray is adequately treated to effect dust suppression throughout the entire material handling system. The control efficiency of spray systems at transfer points is estimated to be between 70 and 95 percent.

RACT for material handling operations must, of course, be site specific and material specific. In most cases, where the material characteristics will not suffer from increased moisture content, water, oil, or chemical sprays offer good control efficiencies at reasonable costs. However, where material characteristics or specifications preclude wetting, the emissions should be controlled by enclosure and ventilation to a fabric filter. Again a case-by-case assessment must be made to ascertain the severity of the emissions and the relative economics of control.

During PEDCo plant visits emissions from storage of materials did not appear to be a major contributor to nonattainment of the NAAQS. Therefore, the only emissions discussed here are from storage facilities that are enclosed. The only emissions from these sources are associated with the transfer of material in and out of storage and are treated in the conveying and transfer section.

Primary crushing operations can constitute a significant emission source. As material is crushed, its surface area is greatly increased. If incoming material has a high internal moisture content, the new surfaces will be moist and nondusting; however, if the material has a low internal moisture content, the crushing greatly increases the potential for generation of airborne dust. These emissions can be controlled by spraying with water, oil, or chemical dust suppressants. This method can be supplemented by venting the crushing area to a fabric filter. A fabric filter should be used if the material is screened after being crushed, as screening requires a low moisture content to avoid blinding of the screens.

Secondary crushing or grinding operations also generate a significant amount of particulate emissions. This operation is similar to that of primary crushing, and the control options are the same.

The control of emissions from screening and sizing is the same as for crushing and grinding with the use of a water, oil, or chemical spray precluded in many cases because the moisture can cause the blinding of the screens for many materials.

The control of emissions from loadout is the same as that for unloading except that material that is loaded out is generally finer than that loaded in and therefore may require a higher degree of control. Also if the moisture content of the product is important, the use of water, oil, or chemical sprays may be precluded.

6.3 CONTROL COSTS

An estimate of the cost of the various control options discussed in the previous subsection is presented in Table 6-2. The universe of materials that may be handled each have different costs of control. The costs and control efficiencies given in this section are given for a specific case and therefore are not applicable to all materials. The estimates should give a ball park estimate that is applicable to most cases.

Material handling operations move what is usually considered to be a "valuable" commodity from one point to another within a given industrial setting. Because the material has been acquired at some cost to the industry, the loss of a portion of this material constitutes a waste. In some cases the cost of installing collection devices can be partially offset by the market value of the material which has been captured. This type of side benefit associated with collection devices have applications in a number of industries. Because of the wide variety of materials handled, no credits are taken in the cost of control calculations in this section.

Costs in Table 6-2 are calculated assuming 500 tons per hour of material handled 8 hours per day, 250 days per year. All costs are in 1980 dollars. Specific cost calculations should be done on a site-specific basis to determine if the cost per ton removed is reasonable.

TABLE 6-2. CONTROL COSTS OF MATERIALS HANDLING[a]

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $		Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal[b], tons/yr			Annual capital[c]	Annual O&M	
Unloading by truck[d]	Partial enclosure	90	1.5[e]	0.150	675.0	50,000[d]	10	8,140	12,500[d]	31
Unloading by truck[d]	Total enclosure/fabric filter	95	1.5[e]	0.075	712.5	76,000[d]	10	12,370	17,000[d]	41
Unloading by truck[d]	Water spray	50	1.5[e]	0.750	375.0	2,500[f]	10	410	80[f]	1
Unloading by ship[d]	Total enclosure/fabric filter	95	0.2[e]	0.010	95.0	51,600[d]	10	8,400	11,600[d]	210
Unloading by rail[d]	Partial enclosure	70	1.5[e]	0.450	525.0	g	g	g	g	g
Unloading by rail[d]	Total enclosure/fabric filter	99	1.5[e]	0.015	675.0	120,000[d]	10	19,530	g	g
Unloading by rail[d]	Chemical spray	80	1.5[e]	0.300	600.0	37,000[d]	10	6,020	g	c
Conveying and transfer[f]	Partial enclosure	80	0.2[d]	0.040	80.0	2,500[f]	10	410	Negligible[f]	5
Conveying and transfer[f]	Total enclosure/fabric filter	95	0.2[f]	0.010	95.0	20,000[f]	10	3,260	800[f]	43
Conveying and transfer[f]	Water spray	70	0.2[f]	0.060	70.0	2,500[f]	10	410	80[f]	7

(continued)

TABLE 6-2 (continued)

Source of emissions	Control options	Control, %	Emissions			Total capital cost, $	Expected life, yr	Cost, $		Cost of removal, $/ton
			Uncontrolled, lb/ton	Controlled, lb/ton	Removal[b], tons/yr			Annual capital[c]	Annual O&M	
Crushing and grinding[d,f]	Partial enclosure	95	0.5[f]	0.025	237.5	1,000[f]	10	160	Negligible[f]	1
Crushing and grinding[d,f]	Total enclosure/fabric filter	99	0.5[f]	0.005	247.5	20,000[f]	10	3,260	800[f]	16
Crushing and and grinding[d,f]	Water spray	70	0.5[f]	0.015	242.5	2,500[f]	10	410	80[f]	2
Screening and sizing[f]	Partial enclo-enclosure	95	0.5[f]	0.025	237.3	1,000[f]	10	160	Negligible[f]	1
Screening and sizing[f]	Total enclosure/fabric filter	99	0.5[f]	0.005	247.5	20,000[f]	10	3,260	800[f]	16
Loadout	h	h	h	h	h	h	h	h	h	h

[a] Costs in January 1980 dollars.

[b] Based on operation for 200 h/yr and a feed rate of 500 tons/h.

[c] Based on a 10 percent cost of capital.

[d] Reference 10.

[e] Reference 11.

[f] Reference 12.

[g] Data not available.

[h] Same as for unloading.

6.4 RECOMMENDED RACT

The controls listed in Tables 6-1 and 6-2 are considered most representative of RACT based on technological and economic feasibility. In general, the application of current technology can completely eliminate visible emissions from materials handling at a reasonable cost. Which specific control will depend on the size of the facility, the material being handled and the use of the material. The use of water sprays is precluded if the moisture content of the material content is important. Because the cost will be higher at small sources, specific economic feasibilities should be considered by enforcement agencies on an individual basis. If the source is vented to a control device, the use of a fabric filter should be capable of controlling emissions to less than 0.03 gr/dscf.

The test method to determine mass emissions should be EPA Method 5.[4] Opacity should be measured by use of EPA Method 9.[5]

SECTION 7

SUMMARY

Section 172(b)(2) of the Clean Air Act as amended August 1977, requires that SIP revisions "provide for the implementation of all reasonably available control measures as expeditiously as practicable." The use of RACT for stationary sources is defined as "the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility."[1] The purpose of this report has been to identify control techniques that best represent RACT for particulate emission sources in TSP nonattainment areas in the State of Florida. These sources include phosphate process operations; portland cement plants; electric arc furnaces; sweat or pot furnaces; materials handling, sizing, screening, crushing, and grinding operations.

7.1 RECOMMENDED EMISSION LIMITS

The RACT emission limits recommended in Sections 2 through 6 are presented in Table 7-1. In support of these limits, the preceding sections have provided the following information for each of the industry categories:

TABLE 7-1. SUMMARY OF RACT RECOMMENDATIONS

Source category	Source	Mass emission limit	Visible emission limit, %	
			Stack	Fugitive
Phosphate process operations	DAP production	0.30 lb/ton of product	20	5
Phosphate process operations	ROP/TSP production	0.30 lb/ton of product	20	5
Phosphate process operations	GTSP production	0.20 lb/ton of product	20	5
Phosphate process operations	NSP production	0.25 lb/ton of product	20	5
Phosphate process operations	MAP production	0.20 lb/ton of product	20	5
Phosphate process operations	AFI (granulation)	0.30 lb/ton of product	20	5
Phosphate process operations	AFI (defluorizing)	0.25 lb/ton of product	20	5
Phosphate process operations	Phosphate rock dryers	0.1 lb/ton rock handled	20	5
Phosphate process operations	Phosphate rock grinding	0.1 lb/ton rock handled	20	5
Phosphate process operations	Ship loading	0.01 lb/ton handled	20	5
Phosphate process operations	Rail loading	0.01 lb/ton handled	20	5
Portland cement plants	Kilns	0.30 lb/ton of feed	20	a
Portland cement plants	Clinker coolers	0.20 lb/ton of feed	20	a

(continued)

TABLE 7-1 (continued)

Source category	Source	Mass emission limit	Visible emission limit, %	
			Stack	Fugitive
Portland cement plants	Finish mills	0.02 gr/dscf	5	5
Sweat or pot furnaces	Furnace	0.05 gr/dscf	10[b]	5
Electric arc furnaces	Furnace	0.006 gr/dscf	5[b]	5
Materials handling, sizing, screening, crushing, and grinding operations	All sources	0.03 gr/dscf	5[b]	5

[a] No fugitive opacity standard.

[b] A higher limit is allowed for one 6-minute period per hour.

A description of the equipment, operations, and products.

A summary of the various sources of particulate emissions and control options at these sources.

An estimate of the costs of various control options (both capital costs and cost in dollars per ton of particulate controlled are considered).

Discussion of various factors, including technological advantages and disadvantages, relative costs, and operation and maintenance considerations that justify the choice of RACT.

7.2 COMPARISON WITH OTHER EXISTING REGULATIONS

One method to judge the strictness and reasonableness of a RACT limit is to compare the proposed regulations with existing regulations. The proposed regulations should be at least as stringent as generally existing regulations. This subsection compares proposed and existing regulations in Region IV for portland cement plants, phosphate process operations, electric arc furnaces, sweat or pot furnaces, and materials handling, sizing, screening, crushing, and grinding operations.

7.2.1 Portland Cement Plants

Four states (Alabama, Florida, North Carolina, and South Carolina) have specific regulations for control of particulate emissions from existing portland cement plants. In the other states, these plants would be subject to control under process weight rate curves for general processes. New sources in all states are subject to New Source Performance Standards (NSPS). Figure 7-1 shows allowable emissions from portland cement plants in Region IV.

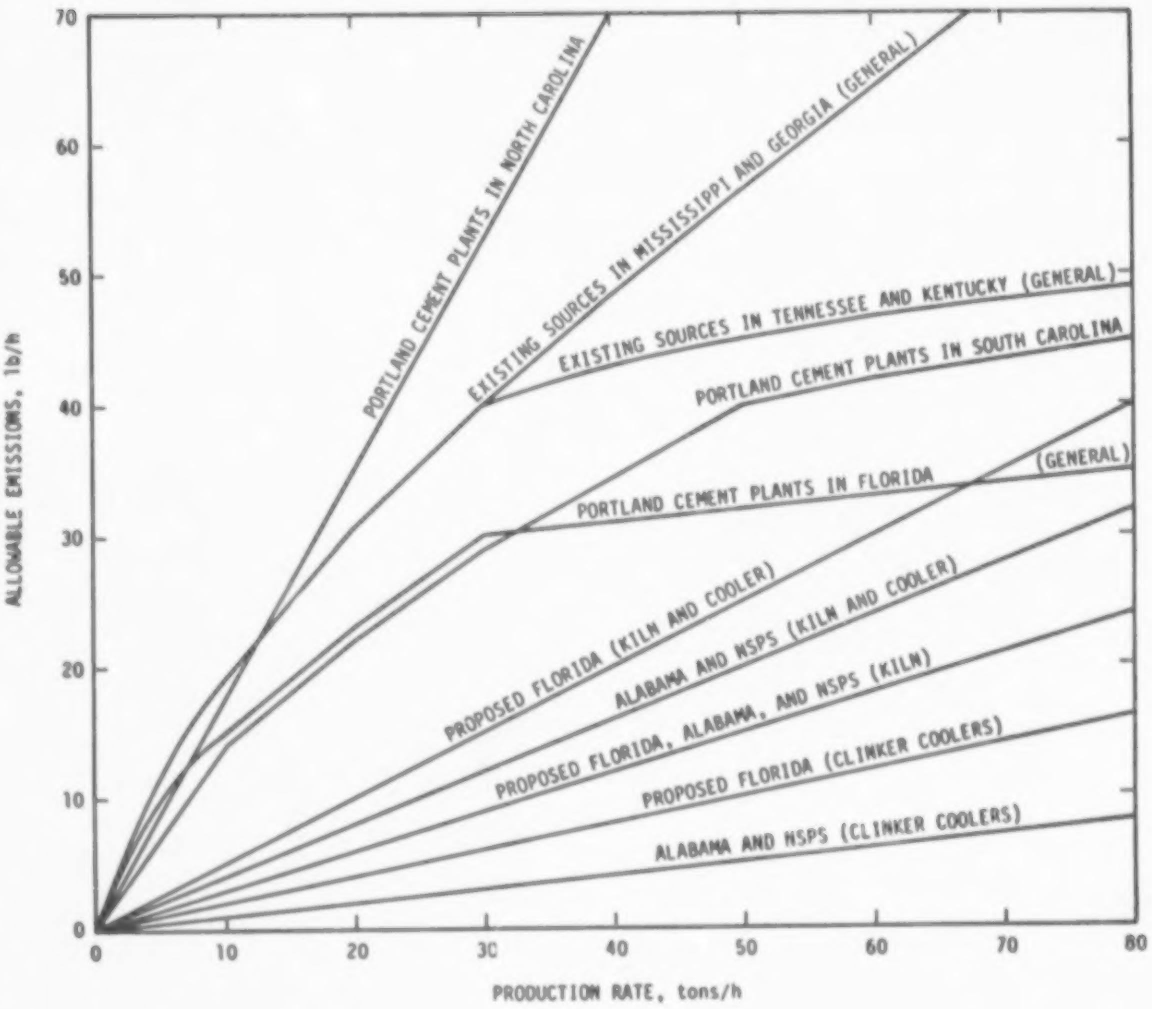

Figure 7-1. Allowable emissions from portland cement plants in Region IV.

7.2.2 Phosphate Process Operations

None of the states in Region IV has existing regulations specifically addressing particulate emissions from phosphate processing operations. Therefore, any plant of this type located in these states would be subject to process weight rate curves for general process sources. Figure 7-2 compares these general regulations with the one proposed for Florida.

7.2.3 Electric Arc Furances

Of the states in Region IV, only Kentucky has a regulation specifically for existing electric arc furnaces. New electric arc furnaces in all states are subject to NSPS. A comparison of these two regulations with the one proposed for Florida is presented in Table 7-2.

7.2.4 Sweat or Pot Furnaces

No state in Region IV has regulations specifically for sweat or pot furnaces. Any new sweat or pot furnace at secondary lead smelters in the region would be subject to NSPS, which prohibit the discharge of gases with greater than 10 percent opacity from pot furnaces of more than 550-pounds charging capacity. In comparison, the proposed emission limits for Florida are 0.05 gr/dscf from existing sweat or pot furnaces and 10 percent opacity.

7.2.5 Materials Handling, Sizing, Screening, Crushing, and Grinding Operations

Current regulations in Region IV states do not set specific emission limits for materials handling, sizing, screening, crushing, and grinding operations. Rather, they require that

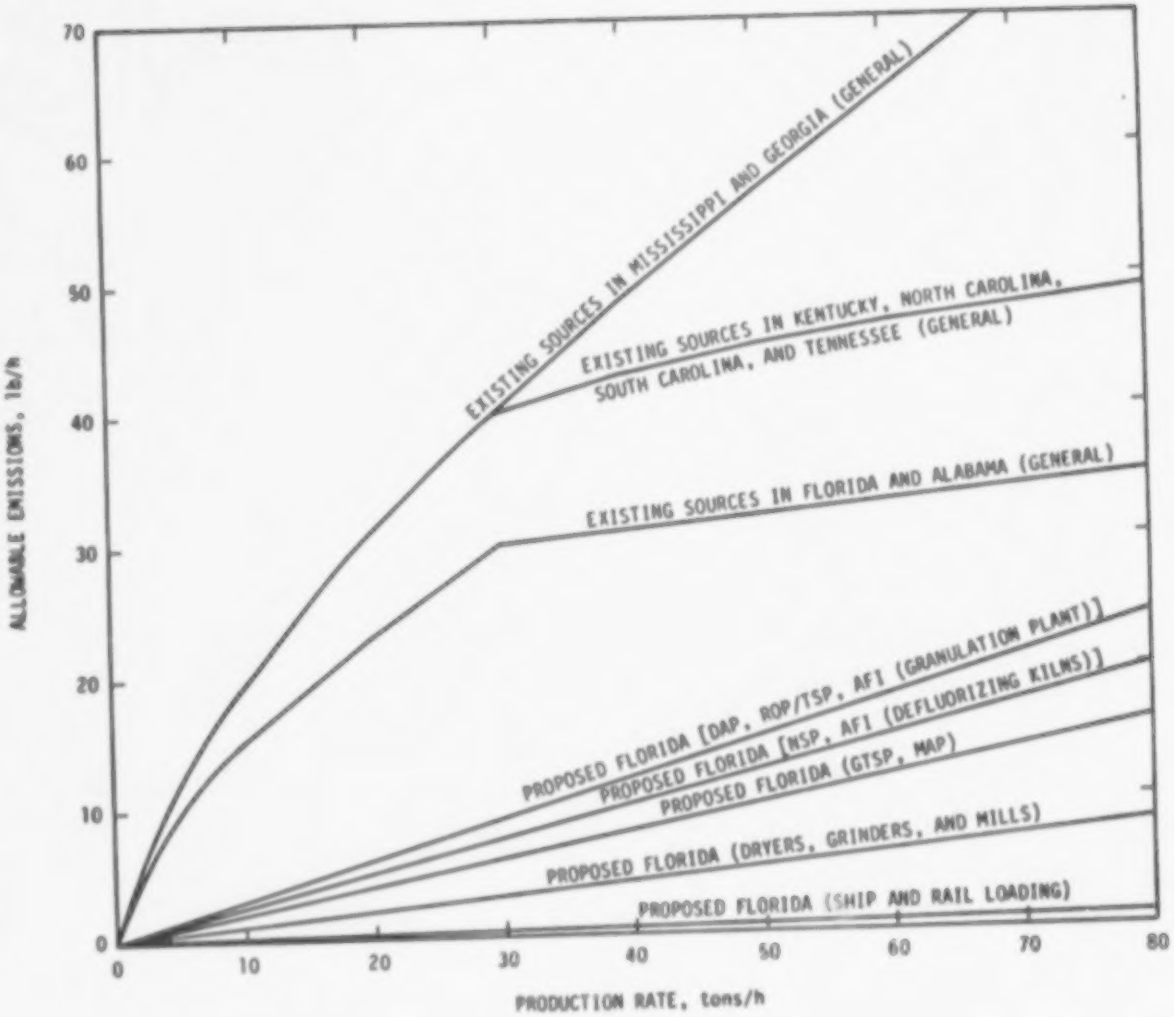

Figure 7-2. Allowable emissions from phosphate processing operations in Region IV.

TABLE 7-2. ALLOWABLE EMISSIONS FROM ELECTRIC ARC FURNACES IN REGION IV

Regulation	Emission limitation	Opacity
Kentucky	0.01 gr/dscf	3 percent from control device, 0 percent from shop
NSPS	0.0052 gr/dscf	3 percent from control device, 0 percent from shop
Proposed Florida	0.006 gr/dscf	5 percent from control device, shop

appropriate control measures be used. These control measures are referred to in regulations by such phrases as "reasonable precautions" and "measures to reduce" and are generally followed by a list of "reasonable precautions." In comparison, the proposed Florida regulations limit emissions to 0.03 gr/dscf from any enclosed operation vented through a stack and a 5 percent opacity. Table 7-3 presents regulations in Region IV.

TABLE 7-3. FUGITIVE DUST REGULATIONS IN REGION IV

State	Capsulized regulation
Alabama	No person shall . . . [list of activities] without taking reasonable precautions to prevent particulate matter from becoming airborne.
Florida	No person shall . . . allow the emissions of particulate matter from any source whatever . . . without taking reasonable precautions to prevent such emission, except [emissions covered by other regulations] . . . .
Georgia	All persons responsible for any operation . . . which may result in fugitive dust shall take all reasonable precautions to prevent such dust from becoming airborne.
Kentucky	No person shall . . . [list of activities] without taking reasonable precautions to prevent particulate matter from becoming airborne.
Mississippi	a) No person shall cause or permit the handling or transporting or storage of any material in a manner which allows or may allow unnecessary amounts of particulate matter to become airborne. b) When dust . . . escape(s) from a building or equipment in such a manner and amount as to cause a nuisance to property other than that from which it originated . . . the Commission may order . . . that all air and gases . . . leaving the building or equipment are controlled . . . . c) No person shall . . . allow . . . particulate fallout to exceed background levels by 5.25 grams/meter squared/month.
North Carolina	
a) Particulates from mica or feldspar processing plants	a) No person shall . . . allow . . . particulate matter caused by processing of mica or feldspar to be discharged from any stack . . . in excess of . . . . $(P \leq 30)$, $E = 4P^{0.677}$ $(30 < P \leq 1000)$, $E = 20.421\ P^{0.1977}$ $(1000 < P \leq 3000)$, $E = 38.147\ P^{0.1072}$ where E is the maximum allowable rate of emission of particulate matter in lb/h, and P is the actual process weight rate in tons/h.

(continued)

TABLE 7-3 (continued)

State	Capsulized regulation
b) Particulates: sand, crushed stone operations	a) No person shall . . . [list of activities] without taking measures to reduce to a minimum any particulate matter from becoming airborne, and in no case shall established ambient air quality standards be exceeded at the property line. b) The owner . . . shall direct control of the plant premises and access roads. c) All stone crushing operations shall employ a water spray over the crusher.
South Carolina	a) All nonenclosed sources shall be operated in such a manner, that a minimum of particulate matter becomes airborne. b) The owner . . . of all sources shall maintain dust control of the premises and roads . . . . c) All crushing, drying, classification and like operations shall employ a suitable control device . . . .
Tennessee	No person shall . . . allow [list of activities] without taking reasonable precautions to prevent particulate matter from becoming airborne.
Florida (proposed regulation)	a) ≤ 5 percent opacity, except for one six-minute period per hour which shall not exceed 20 percent. b) 0.03 gr/dscf from the stack of an enclosed operation.

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APPENDIX

SUMMARY OF CONTROL AND EMISSIONS DATA FOR PHOSPHATE INDUSTRY

DAP

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	50	reactor/granulator	venturi	9.50	0.19
		cooler/screens	venturi cross flow		
		dryer	venturi		
2	55	reactor	venturi/cyclonic	2.41	0.20
		screens/mills	venturi/cyclonic	1.75	
		dryer	venturi/cyclonic	7.19	
3	70	reactor/granulator	venturi/cyclonic	1.28	0.75
		screens/mills/dryer	venturi/cyclonic	18.88	
		cooler	wet cyclone	32.50	
4	35	granulator	venturi/packed bed	11.00	0.31
		screens/dryer			
5	50	granulator	venturi/packed bed	12.00	0.24
		screens/dryer			
6	30	dryer/screens	venturi/cross flow	16.00	0.53
		cooler, saturator			
		blunger			
7	30	dryer/screens	venturi/cross flow	16.8	0.54
		cooler, saturator			
		blunger			
8	98	dryer, reactor	packed bed/cross flow	11.00	0.11
		screens, cooler			
9	35	reactor, screen	venturi/cross flow	4.70	0.13
		cooler, dryer			
10	25	reactor/screens	venturi/cyclonic	2.19	0.64
		reactor/screens	venturi/cyclonic	2.69	
		cooler	wet cyclone	21.71	
11	24	reactor/screens	venturi/cyclonic	2.96	0.95
		reactor/screens	venturi/cyclonic	3.40	
		cooler	wet cyclone	31.8	

MAP

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	25	prill tower cooler	venturi/cross flow	3.0	0.12
2	14	prill tower	venturi/cross flow	2.69	0.19

GTSP

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	63	reactor, dryer screens, granulator	venturi/cross flow	10.88	0.17
2	31	dryer, screens granulator, cooler	venturi/cross flow	2.4	0.07
3	66	dryer		8.50	0.12
4	33	dryer/screens mill/blunger reactor	venturi/packed	12.4	0.37
5	72	dryer/screens mill/reactor	venturi/packed	11.00	0.15

ROP/TSP

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	18	belt dryer	cyclonic cyclonic	1.40 4.55	0.32
2	48	belt dryer	cyclonic cyclonic	6.50 6.40	0.43
3	40	dryer/screen belt	venturi/cross flow	8.00	0.27
4	45	den	venturi	2.1	0.04
5	45	den	cyclonic	6.2	0.14

NSP

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	15	curing den	wet impingement	1.90	0.01
2	13	curing den	cyclonic	2.0	0.15
3	15.7	curing den	cyclonic	0.36	0.023

PHOSPHATE ROCK DRYING

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Emission rate lb/ton
1	475	fluidized bed dryer	impingemet scrubber	16.0	0.034
2	350	fluidized bed dryer	cyclonic scrubber	17.8	0.050
3	230	fluidized bed dryer	venturi scrubber	19.2	0.084
4	230	rotary dryer	venturi scrubber	16.4	0.071
5	85	unknown type dryer	venturi scrubber	25.5	0.30
6	270	rotary dryer	venturi scrubber	8.35	0.031
7	470	fluidized bed dryer	cyclonic scrubber	9.10	0.019
8	470	fluidized bed dryer	cyclonic scrubber	14.9	0.032
9	200	unknown type dryer	venturi scrubber	8.2	0.041
10	520	unknown type dryer	cyclonic scrubber	18.6	0.036
11	200	unknown type dryer	venturi scrubber	16.6	0.083
12	500	unknown type dryer	venturi scrubber	28.5	0.057
13	3	rotary dryer	cyclone & scrubber	0.84	0.28
14	330	rotary dryer	venturi scrubber	5.2	0.016

PHOSPHATE ROCK DRYING MATERIAL HANDLING

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	2700	dry rock transfer	pulse baghouse	2.3	0.00085
2	2700	storage transfer	venturi scrubber	6.84	0.0025
3	420	dry rock transfer	impingement scrubber	0.13	0.00031
4	950	dry rock transfer	cyclonic scrubber	0.50	0.00053
5	296	dry rock transfer	cyclonic scrubber	0.42	0.0014

PHOSPHATE ROCK GRINDING

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	1.1	grinding mill	venturi scrubber	2.2	2.0
2	40	grinding mill	pulse baghouse	27.8	0.69
3	36	grinding mill	pulse baghouse	0.20	0.0055
4	230	grinding mill	pulse baghouse	4.3	0.019
5	230	grinding mill	pulse baghouse	4.3	0.019
6	168	grinding mill	pulse baghouse	0.50	0.003
7	12	Raymond mill	pulse baghouse	0.77	0.063
8	12	Raymond mill	pulse baghouse	1.4	0.11
9	12	Raymond mill	pulse baghouse	0.77	0.063
10	115	Raymond mill	pulse baghouse	2.7	0.023
11	40	ball mill	pulse baghouse	4.17	0.10
12	120	ball mill	pulse baghouse	32.6	0.27
13	120	ball mill	pulse baghouse	30.0	0.25
14	100	ball mill	pulse baghouse	27.0	0.27
15	35	grinding mill	pulse baghouse	2.0	0.057
16	60	grinding mill	pulse baghouse	6.4	0.11
17	90	ball mill	pulse baghouse	11.0	0.12
18	24	Raymond mill	venturi scrubber	1.7	0.070

PHOSPHATE ROCK GRINDING MATERIAL HANDLING

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	150	ground rock transfer	pulse baghouse	1.9	0.013
2	15	ground rock unloading	pulse baghouse	0.14	0.0093
3	70	ground rock storage	pulse baghouse	0.28	0.004

PHOSPHATE ROCK RAIL LOADOUT

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	750	rail loadout	cyclonic scrubber	1.2	0.0016
2	900	rail loadout	venturi scrubber	18.5	0.021

PHOSPHATE ROCK SHIPLOADING

Plant number	Process weight ton/hr	Controlled sources	Control devices	Emission rate lb/hr	Total plant emission rate lb/ton
1	2700	shiploader	pulse baghouse	9.85	0.0036
2	800	shiploader	pulse baghouse	0.10	0.00013
3	800	shiploader	pulse baghouse	0.20	0.00025